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Appendix D Acoustic and Explosive Impacts Supporting Information

APPENDIX D

ACOUSTIC AND EXPLOSIVE IMPACTS SUPPORTING INFORMATION

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Environmental Impact Statement/
Overseas Environmental Impact Statement
Hawaii-California Training and Testing
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APPENDIX D ACOUSTIC AND EXPLOSIVE IMPACTS SUPPORTING INFORMATION

This appendix contains several sections that provide brief explanations of acoustic terminology and concepts, information on the existing acoustic environment, and thorough synthesis of the best available science on acoustic and explosive impacts to marine mammals, reptiles, and fishes. This appendix is written by a team of expert bioacoustic scientists and is updated as needed as relevant scientific studies are published.

D.1 ACOUSTIC AND EXPLOSIVE CONCEPTS / PRIMER

This section briefly explains the transmission of sound and explosive energy underwater and in air; introduces some of the basic mathematical formulas used to describe propagation; and defines acoustical terms, abbreviations, and units of measurement. Methods used to analyze hearing are also described.

For a more extensive background on acoustics, explosives, and marine bioacoustics the following resources are recommended:

- *Marine Mammals and Noise* (Richardson et al., 1995b)
- *Principles of Underwater Sound* (Urick, 1983)
- *Fundamentals of Acoustical Oceanography* (Medwin & Clay, 1998)
- *Principles of Marine Bioacoustics* (Au & Hastings, 2008)
- *Exploring Animal Behavior Through Sound: Volume 1 Methods* (Erbe & Thomas, 2022)
- *Discovery of Sound in the Sea* (https://dosits.org/)

D.1.1 TERMINOLOGY

The following terms are used in this document when discussing sound and the attributes of a sound source.

D.1.1.1 Sound

Sound is produced when an elastic medium (such as air or water) is set into motion, typically by a vibrating object within the medium. As the object vibrates, its motion is transmitted to adjacent "particles" of the medium. The motion of these particles is transmitted to adjacent particles, and so on. The result is a mechanical disturbance (the "sound wave") that moves away from the source and propagates at a medium-dependent speed (the "sound speed"). As the sound wave travels through the medium, the individual particles of the medium oscillate about their original positions but do not actually move with the sound wave. This particle movement creates small changes in the medium's density, pressure, and temperature.

Sound may be described by both physical and subjective attributes. Physical attributes, such as sound amplitude and frequency, may be directly measured. Subjective (or sensory) attributes like loudness depend on an animal's perception of sound, and can vary between species and individuals.

D.1.1.2 Signal Versus Noise

When sound is purposely created to convey information, communicate, or obtain information about the environment, it is often referred to as a signal. Examples of signals include sonar pings, marine mammal vocalizations and echolocation clicks, tones used in hearing experiments, and small sonobuoy explosions used for submarine detection. Typically, signals have some type of known characteristics, for example, they could use a limited set of frequencies, have a specific set of harmonics, or be used such that the pulse context provides information to a receiver.

Noise is defined as any undesired sound (American National Standards Institute, 2013) that typically lacks the clear characteristics previously described. Sounds produced by naval aircraft and vessel propulsion are considered noise because they represent possible inefficiencies within the system and increased detectability by adversaries. Whether a sound is perceived as noise depends on the receiver (i.e., the animal or system that detects the sound). For example, small explosions and sonar pings used to generate sounds to locate enemy submarines produce signals that are useful to sailors engaged in anti-submarine warfare, but are assumed to be noise when detected by marine species.

The combination of all sounds (including signals and noise) at a particular location, whether these sources are located near or far, is defined as ambient noise (American National Standards Institute, 2013). Ambient noise includes natural sources such as sound from crashing waves, rain, and animals (e.g., snapping shrimp), and anthropogenic sources such as seismic surveys and vessel noise. Every location in the marine environment contains some ambient noise, but how much depends on a multitude of factors. Characterizing the ambient noise level of a location is imperative to understanding potential impacts to marine life from anthropogenic sound.

D.1.1.3 Frequency and Wavelength

Frequency is the physical attribute associated with the subjective attribute "pitch", the higher the frequency, the higher the pitch. Frequency is defined by the number of oscillations (i.e., cycles) in the sound pressure or particle motion per second. One hertz (Hz) is equal to one oscillation per second, and one kilohertz (kHz) is equal to 1,000 oscillations per second. "Bandwidth" refers to the range between the minimum and maximum frequency of a sound source or receiver.

Pure tones have energy at a constant, single frequency. Complex tones contain energy at multiple, discrete frequencies, rather than a single frequency. A harmonic of a sound at a particular frequency is a multiple of that frequency. For example, harmonic frequencies of a 2 kHz fundamental frequency tone (i.e., the lowest and most intense frequency of a complex tone) are 4 kHz, 6 kHz, 8 kHz. A source operating at a nominal frequency may emit several harmonic frequencies, but at lower amplitudes and higher frequencies. Some sources may also emit subharmonics which are lower in frequency than the fundamental frequency; however, these are typically many orders of magnitude less powerful than the fundamental frequency. Sounds with large bandwidths ("broadband" sounds) have energy spread across many frequencies.

In this document, sounds are generally described as either low- (less than 1 kHz), mid- (1 kHz to 10 kHz), high- (10 kHz to 100 kHz), or very high- (greater than 100 kHz) frequencies. Hearing ranges of marine animals (e.g., fishes, birds, sea turtles, and marine mammals) are variable and species dependent. For example, some fishes can detect sounds below 100 Hz and some species of marine mammals have hearing capabilities that extend above 100 kHz. Therefore, acoustic impact analyses must focus on the sound amplitude (i.e., pressure or particle motion, see Section D.1.1.4, Sound Amplitude), in addition to the sound frequency and animal sensory capabilities.

The wavelength of a sound is the distance between wave peaks. Wavelength decreases as frequency increases. The frequency multiplied by the wavelength equals the speed of sound in a medium, as shown in this equation:

$$\text{sound speed (m/s)} = \text{frequency}\left(\frac{1}{s}\right) \text{x wavelength (m)}$$

The approximate speed of sound in sea water is 1,500 meters per second (m/s) and in air is 340 m/s, although speed varies depending on environmental conditions (e.g., pressure, temperature, and, in the case of sea water, salinity; see Section D.1.3.1, Speed of Sound).

D.1.1.4 Sound Amplitude

Sound amplitude is the physical attribute associated with the subjective attribute loudness. Amplitude is related to the amount that the medium particles oscillate about their original positions and can be thought of as the "strength" of a sound (as the amplitude increases, the loudness also increases). As the sound wave travels, the particles of the medium oscillate and transfer energy from one particle to another but do not actually travel with the wave. The result is a mechanical disturbance (i.e., the sound wave) that propagates energy away from the sound source. Sound amplitude is typically characterized by measuring the acoustic pressure or particle motion.

D.1.1.5 Impulsive Versus Non-Impulsive Sounds

Although no standard definitions exist, sounds may be broadly categorized as impulsive or non-impulsive. Impulsive sounds have short durations, rapid rise-times, broad frequency content, and high peak pressures. Impulsive sounds are often produced by processes involving a rapid release of energy or mechanical impacts (Hamernik & Hsueh, 1991). Explosions and weapons firing are examples of impulsive sound sources analyzed in this document. In contrast, sonar, vessel operation, and underwater transducers lack the characteristics of impulsive sound sources and are thus examples of non-impulsive sound sources. Non-impulsive sounds can be essentially continuous, such as machinery noise, or intermittent, such as sonar pings. Impulsive signals, particularly at close range, are characterized as brief and broadband with rapid rise time and higher instantaneous peak pressure than other signal types. However, because of propagation effects, an impulsive signal can lose those characteristics, and at a variable distance it could be characterized as a non-impulsive signal (Hastie et al., 2019; Martin et al., 2020).

D.1.1.6 Acoustic Impedance

Acoustic impedance is a property of the propagation medium (air, water, sediment, or tissue) that can be simply described as the opposition to the flow of a pressure wave. Acoustic impedance is a function of the density and speed of sound in a medium. Sound transmits more readily through materials of similar acoustic impedance, such as water and animal tissue, since soft tissue is mainly comprised of water. When sound waves encounter a medium with different acoustic impedance (for example, an air-water interface), they reflect and refract (see Sections D.1.3.3.3, Refraction, and D.1.3.3.4, Reflection and Multipath Propagation), creating more complex propagation conditions. For example, sound traveling in air (low impedance) encountering the water surface (high impedance) will be largely reflected, preventing most sound energy in the air from being transmitted into the water. The impedance difference at the tissue-air interface in animals with gas-containing organs also makes these areas susceptible to damage when exposed to the shock wave near an explosion. Transmission from high-impedance to low-impedance can result in large motion at the boundary.

D.1.1.7 Duty Cycle

Duty cycle describes the portion of time that a source generates sound. It is defined as the ratio of time that a signal or system is on compared to the time it is off during an operational period. For example, if a sonar source produces a one-second ping once every 10 seconds, the duty cycle is 10 percent. Duty cycles vary within and between different acoustic sources; in general, a duty cycle of 20 percent or less is considered low, and a duty cycle of 80 percent or higher is considered high.

D.1.1.8 Resonance

Resonance occurs when an object is vibrated at a frequency near its "natural frequency" or resonant frequency. The resonant frequency can be considered the preferred frequency at which an object will oscillate at a greater magnitude than when exposed to other frequencies. In this document, resonance is considered in relation to the size of an air bubble or air cavity (e.g., lungs). Biological life exposed to high pressure waves from an outside source can lead to potential injury. Due to an inverse relationship, the smaller the bubble, the higher the resonant frequency. The natural frequency of biological life would vary based on the size of the bubbles trapped within them. For example, large whale lungs would have a lower resonant frequency than dolphin lungs. The natural frequencies of dolphin and beluga lungs near the surface are about 36 Hz and 30 Hz, respectively (Finneran, 2003). As an animal dives deep within the water column, there is a corresponding increase in pressure. Hence, any air bubbles trapped within the animal would likely shrink as a result of the pressure change (Bostrom et al., 2008). Because of the change in bubble size, the resonant frequencies would tend to increase as an animal dives.

D.1.2 Sound Metrics

The sound metrics described here are used to quantify exposure to a sound or explosion.

D.1.2.1 Pressure

Sound pressure is the incremental variation in a medium's static pressure (i.e., the ambient pressure without the added sound) as a sound wave travels through it. Sound pressure is typically expressed in units of micropascals (µPa), although explosive overpressure may also be described in pounds per square inch (psi).

Various sound pressure metrics are illustrated in Figure D.1-1 for (a) a non-impulsive sound (a pure tone in this illustration) and (b) an impulsive sound. As shown in Figure D.1-1, the non-impulsive sound has a relatively gradual rise in pressure from static pressure, while the impulsive sound has a near-instantaneous rise to a high peak pressure. The peak pressure shown on both illustrations is the maximum absolute value of the instantaneous sound pressure during a specified time interval ("zero-to-peak" or "peak"). "Peak-to-peak" pressure is the difference between the maximum and minimum sound pressures.

The root-mean-square (rms) value is often used to describe the average sound pressure level (SPL). SPLs provided in this Environmental Impact Statement (EIS)/Overseas EIS (OEIS) are root-mean-square values unless otherwise specified. As the name suggests, this method takes the square root of the average squared sound pressure values over a time interval. The duration of this time interval can have a strong effect on the measured rms sound pressure for a given sound, especially where pressure levels vary significantly, as during an impulsive sound exposure. If the analysis duration includes a large portion of the waveform after the sound pressure has returned to zero, the rms pressure would be relatively low. If the analysis duration includes only the highest pressures of the impulsive exposure, the rms value would be comparatively high. For this reason, it is important to specify the duration used to calculate the rms pressure for impulsive sounds.

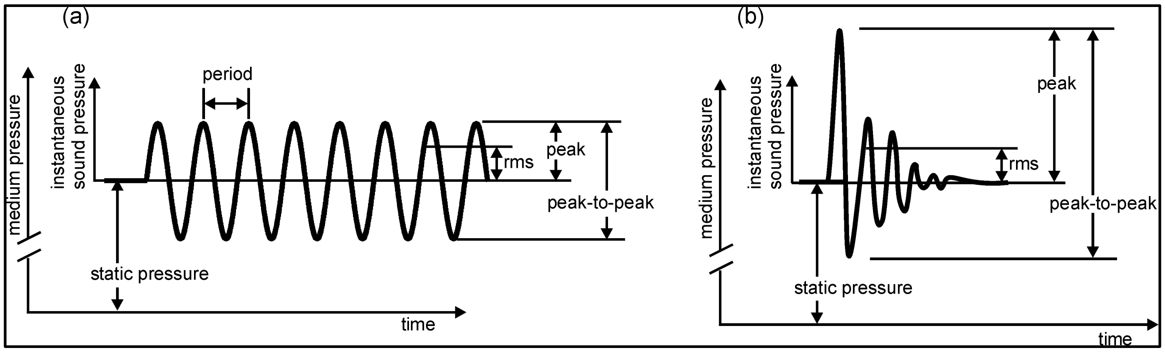


Figure D.1-1: Various Sound Pressure Metrics for a Hypothetical (a) Pure Tone (Non-Impulsive) and (b) Impulsive Sound

D.1.2.2 Sound Pressure Level

The most common sound level metric is SPL. Because many animals can detect very large pressure ranges and judge the relative loudness of sounds by the ratio of the sound pressures (a logarithmic behavior), SPL is described by taking the logarithm of the ratio of the sound pressure to a reference pressure. Use of a logarithmic scale compresses the wide range of measured pressure values into a more useful scale.

SPLs are normally expressed in decibels. A decibel is 1/10 of a bel, a unit of level when the logarithm is to the base ten and the quantities concerned are proportional to power (American National Standards Institute, 2013). SPL in decibels is calculated as follows:

$$SPL = 20\log_{10}\left(\frac{P}{P_{ref}}\right)$$

where P is the sound pressure and P_{ref} is the reference pressure. Unless stated otherwise, the pressure (P) is the rms value of the pressure (American National Standards Institute, 2013). In some situations, SPL is calculated for the peak pressure rather than the rms pressure. On the occasions when rms pressure is not used, the pressure metric will be stated (e.g., peak SPL means an SPL calculated using the peak pressure rather than the rms pressure).

When a value is presented in decibels, it is important to also specify the value and units of the reference quantity. Normally the numeric value is given, followed by the text "re," meaning "with reference to," and the numeric value and unit of the reference quantity. For example, a pressure of 1 Pa, expressed in decibels with a reference of 1 micropascal (µPa), is written 120 dB re 1 µPa. The standard reference pressures are 1 µPa for water and 20 µPa for air. The reference pressure for air, 20 µPa, is the approximate lowest threshold of human hearing. It is important to note that because of the differences in reference units, the same sound pressures would result in different SPL values for each medium (the same sound pressure measured in water and in air would result in a higher SPL in water than in air, since the in-air reference is larger). Therefore, SPLs in air and in water cannot be directly compared.

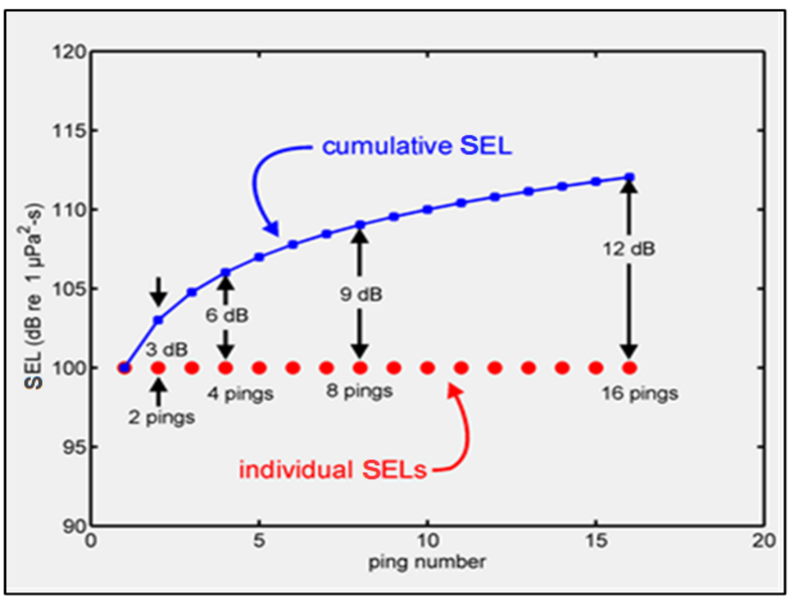
D.1.2.3 Sound Exposure Level

Sound exposure level (SEL) can be thought of as a composite metric that represents both the SPL of a sound and its duration. Individual time-varying noise events (e.g., a series of sonar pings or an impulsive sound) have two main characteristics: (1) a sound pressure that changes throughout the event and (2) a period during which a receiver is exposed to the sound. SEL can be provided for a single exposure (i.e., a single sonar ping or single explosive detonation) or for an entire acoustic event (i.e., multiple sonar pings or multiple explosive detonations). Cumulative SEL provides a measure of the net exposure of the entire acoustic event, but it does not directly represent the sound level at a given time. SEL is determined by calculating the decibel level of the cumulative sum-of-squared pressures over the duration of a sound, with units of dB re 1 micropascal squared seconds (re 1 $\mu Pa^2 s$) for sounds in water, and dB re 20 micropascal squared seconds (re 20 $\mu Pa^2 s$) for sounds in air.

Guidelines for SEL are as follows:

- The numeric value of SEL is equal to the SPL of a one-second sound that has the same total energy as the exposure event. If the sound duration is one second, SPL and SEL have the same numeric value (but not the same reference quantities). For example, a one-second sound with an SPL of 100 dB re 1 µPa has a SEL of 100 dB re 1 $\mu Pa^2 s$.
- If the sound duration is constant but the SPL changes, SEL will change by the same number of decibels as the SPL.
- If the SPL is held constant and the duration (T) changes, SEL will change as a function of $10\log_{10}(T)$:
  - $10 \log_{10}(10) = 10$, so increasing duration by a factor of 10 raises SEL by 10 dB.
  - $10 \log_{10}(0.1) = -10$, so decreasing duration by a factor of 10 lowers SEL by 10 dB.
  - $10 \log_{10}(2) \approx 3$, so doubling the duration increases SEL by 3 dB.
  - $10 \log_{10}(1/2) \approx -3$, so halving the duration lowers SEL by 3 dB.

Figure D.1-2 illustrates the summation of energy for a succession of sonar pings. In this hypothetical case, each ping has the same duration and SPL. The SEL at a particular location from each individual ping is 100 dB re 1 $\mu Pa^2 s$ (red circles). The upper, blue curve shows the running total or cumulative SEL.

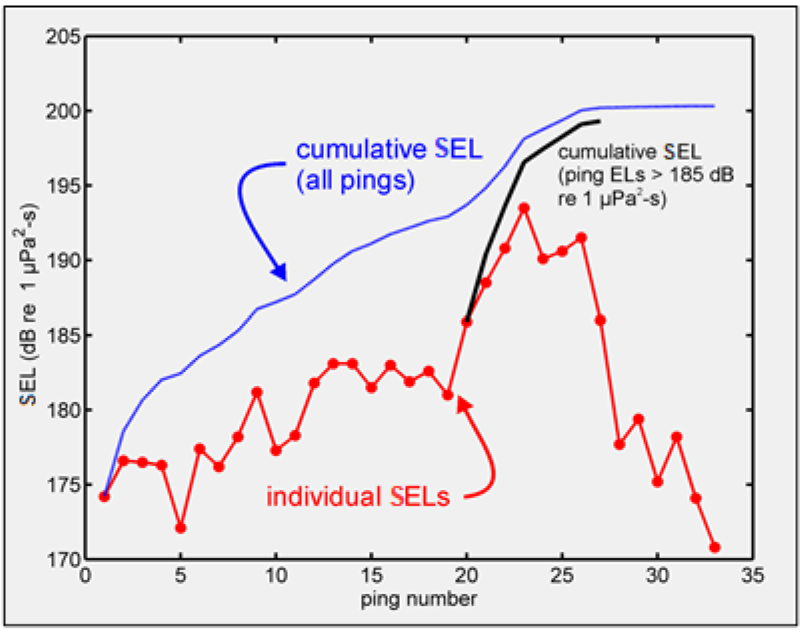


Note: dB = decibels; SEL = sound exposure level; dB re 1 μPa^2-s = decibels with a reference of 1 micropascal (µPa) squared per second

Figure D.1-2: Summation of Acoustic Energy from a Hypothetical, Intermittently Pinging, Stationary Sound Source

After the first ping, the cumulative SEL is 100 dB re 1 µPa^{2}s. Because each ping has the same duration and SPL, receiving two pings is the same as receiving a single ping with twice the duration. The cumulative SEL from two pings is therefore 103 dB re 1 µPa^{2}s. The cumulative SEL from four pings is 3 dB higher than the cumulative SEL from two pings, or 106 dB re 1 µPa^{2}s. Each doubling of the number of pings increases the cumulative SEL by 3 dB.

Figure D.1-3 shows a more realistic example where the individual pings do not have the same SEL. These data were recorded from a stationary hydrophone as a sound source approached, passed, and moved away from the hydrophone. As the source approached the hydrophone, the received SEL of each ping increased. After the source passed the hydrophone, the received SEL from each ping decreased as the source moved farther away (downward trend of red line), although the cumulative SEL increased with each additional ping received (slight upward trend of blue line). The main contributions are from those pings with the highest individual SELs. Individual pings with SELs 10 dB or more below the ping with the highest level contribute little (less than 0.5 dB) to the total cumulative SEL. This is shown in Figure D.1-3, where only a small error is introduced by summing the energy from the eight individual pings with SEL greater than 185 dB re 1 µPa^{2}s (black line), as opposed to including all pings (blue line).



Note: dB = decibels; ELs = exposure levels; SEL = sound exposure level; dB re 1 µPa^2-s = decibels with a reference of 1 micropascal (µPa) squared per second

Figure D.1-3: Cumulative SEL under Realistic Conditions with a Moving, Intermittently Pinging Sound Source

D.1.2.4 Particle Motion

The particles of a medium (e.g., water or air) oscillate around their original position as a sound wave passes through. Particle motion comprises particle displacement (m or dB re 1 pm), particle velocity (m/s or dB re 1 nm/s^2), and particle acceleration (m/s^2 or dB re 1 µm/s^2) (Nedelec et al., 2016a). Note that particle velocity is not the same as sound speed, which is how fast a sound wave moves through a medium. Particle motion is also directional, whereas sound pressure measurements are not (Nedelec et al., 2016a).

Near acoustic boundaries (e.g., the sea floor and sea surface) and in the shallow waters, the relationship between sound pressure and particle motion is complex and it is necessary to measure particle motion directly (Pierce, 1989). At distances far from a sound source (i.e., in the far field) and without boundary interactions that could cause wave interference, particle velocity is directly proportional to sound pressure. However, closer to a sound source (i.e., in the near field), the particle velocity component of the field contains more energy than the sound pressure component of the field. The rate of decline of particle velocity in the near field depends on the nature of the sound source and its movement pattern (Harris & van Bergeijk, 1962). The distance from a source at which the near field transitions to the far field is related to the wavelength of the signal, with a greater distance for lower frequencies.

D.1.2.5 Intensity

The intensity of a sound wave (I) is defined as the amount of energy per second (power in units Watts) propagating through 1 square meter of a medium (e.g., seawater). A propagating sound wave carries both kinetic energy of a medium's particles in motion (particle velocity [u]) and potential energy due to the acoustic impedance of the medium (sound pressure [p]) and is calculated as follows:

$$I = pu$$

Intensity and velocity are both vector quantities with a magnitude and direction. The motion of particles in a sound wave are generally oriented in the direction of propagation at a velocity equal to the velocity of sound (c). In a plane wave, the sound pressure is related to the particle velocity by:

$$p = \rho c u, \text{ or } u = \frac{p}{\rho c}$$

Where the fluid density (ρ) and velocity of sound (c) are known as the specific acoustic impedance of the medium. Therefore, for a plane wave, the instantaneous intensity is related to the instantaneous sound pressure by:

$$I = \frac{p^2}{\rho c}$$

D.1.2.6 Impulse

Impulse is a metric used to describe the pressure and time component of a pressure wave. Impulse is typically only considered for high-energy exposures to impulsive sources, such as exposures of marine species close to explosives. Specifically, pressure impulse is the time integral of the pressure with units of Pascal-seconds (Pa-s). Impulse is a measured quantity that is distinct from the term "impulsive," which is not a measurement term, but rather describes a type of sound (see Section D.1.1.5, Impulsive Versus Non-Impulsive Sounds).

D.1.3 Predicting How Sound Travels in Water

While the concept of a sound wave traveling from its source to a receiver is straightforward, sound propagation is complex because of the simultaneous presence of numerous sound waves of different frequencies and source levels (i.e., the sound radiated by a projector). Waves undergo changes in direction (i.e., reflection, refraction, and diffraction) that can cause interferences (waves adding together or cancelling one another out). Ocean bottom types, water density, and surface conditions also affect sound propagation. While simple examples are provided here for illustration, the Navy Acoustic Effects Model used to quantify acoustic exposures to marine mammals and sea turtles considers the influence of multiple factors to predict acoustic propagation [see technical report *Quantifying Acoustic*

Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing (U.S. Department of the Navy, 2024b).

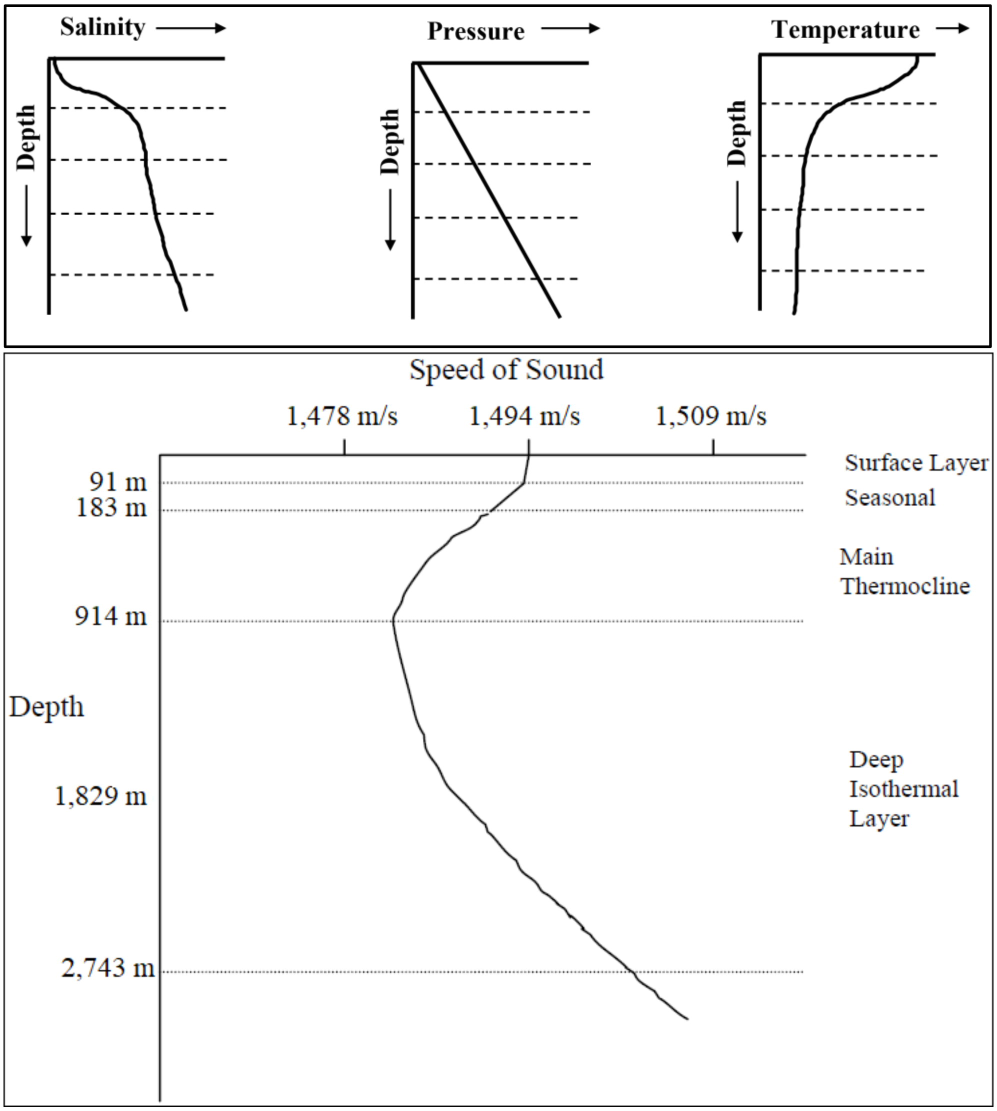
D.1.3.1 Speed of Sound

The speed of sound is not affected by the SPL or frequency of the sound, but depends wholly on characteristics of the medium through which it is passing. The speed of sound (c) is calculated using the bulk modulus (B), which describes resistance to compression, and density (ρ) of seawater, which are influenced by the pressure and temperature of the medium.

$$c = \sqrt{\frac{B}{\rho}}$$

Sound travels faster through a medium that is harder to compress. For example, water is more difficult to compress than air, and sound travels approximately 340 m/s in air and 1,500 m/s in seawater. The density of air is primarily influenced by temperature, relative humidity, and pressure, because these attributes affect the density and compressibility of air. Generally, the speed of sound in air increases as air temperature increases. The density of seawater is primarily influenced by temperature, pressure, and salinity. In general, the density is higher for colder temperatures, higher hydrostatic pressure, and higher salinity. The speed of sound in seawater also increases with increasing temperature and, to a lesser degree, with increasing hydrostatic pressure and salinity.

The combination of effects from temperature, pressure, and salinity creates a sound velocity profile. Figure D.1-4 shows the independent relationship each of these three attributes have with depth. For most areas of the ocean, temperature decreases from the surface to the bottom, although there are many local variations. Shallow layers see the most variation with time and depth (e.g., surface mixing, solar heating, currents, seasonal variations), and at deeper layers the temperature becomes relatively constant at 4°C. Hydrostatic pressure makes the speed of sound increase with depth because of variations in the bulk modulus. Below 1,500 meters (m), the increasing hydrostatic pressure is the dominant factor on sound speed. The change in the mix of pure water and dissolved salts affects the speed of sound. Salinity has minimal variation with depth, but there can be stronger variations near areas with freshwater inputs such as river estuaries and melting ice. Inhomogeneities in seawater can also affect the speed of sound and include bubble layers close to the surface, mineral particles in suspension, and living organisms.



Note: m = meters; m/s = meters per second

Figure D.1-4: Sound Velocity Profile (Sound Speed) Is Related to Temperature, Salinity, and Hydrostatic Pressure of Seawater

Figure D.1-4 also shows an example of a standard sound velocity profile and its four distinctive layers:

The surface layer tends to be irregular and is influenced by diurnal (i.e., daily) heating and cooling; mixing from currents, local wind action, and storms; and changes in salinity due to evaporation, precipitation, freezing, ice melt, and river runoff. The surface layer may contain a mixed layer of isothermal (i.e., nearly constant temperature) water that traps sound. Under prolonged calm and sunny conditions, the mixed layer does not exist and water temperature decreases with depth. The seasonal thermocline (i.e., temperature gradient) is influenced by seasonal heating and cooling and mixing from wind action and storms. The seasonal thermocline is characterized by temperature decreasing with depth. During the summer and fall when waters are warm, the seasonal thermocline is well defined. However, during winter and spring or in cold waters, the seasonal thermocline can be indistinguishable from the surface layer. The main, or permanent thermocline, is independent of the surface layer, is only slightly affected by seasonal changes within a localized area and is where the major temperature difference between the cold depths of the sea occurs. The main thermocline extends to about 300 m and marks the limit where temperature has the most influence on sound velocity due to less mixing at greater depths. The deep isothermal layer is defined by a nearly constant temperature and sound velocity is mainly influenced by pressure. At the inflection point where sound velocity decreases with depth in the main thermocline, and where sound velocity begins to increase in the deep isothermal layer, is where a sound velocity minimum occurs and sound at depth is focused by refraction.

D.1.3.2 Source Directivity

Most sonar and other active acoustic sources do not radiate sound in all directions, unlike noise from vessels and explosions for example. Rather, they emit sounds over a limited range of angles to focus sound energy on a specific area or object of interest. The specific angles are sometimes given as horizontal or vertical beam width. Some sources can be described qualitatively as "forward-looking," when sound energy is radiated in a limited direction in front of the source, or "downward-looking," when sound energy is directed toward the bottom.

D.1.3.3 Transmission Loss

As a sound wave passes through a medium, the sound level decreases with distance from the sound source. This phenomenon is known as transmission loss (TL). The transmission loss is used to relate the source SPL (SL), defined as the SPL produced by a sound source at 1 m, and the received SPL (RL) at a particular location, as follows:

$$RL = SL - TL$$

The main contributors to transmission loss are as follows (Urick, 1983) and are discussed in detail below:

- Geometric spreading of the sound wave as it propagates away from the source
- Sound absorption (conversion of sound energy into heat)
- Scattering, diffraction, multipath interference, and boundary effects

D.1.3.3.1 Spreading Loss

Spreading loss is a geometric effect representing the regular weakening of a sound wave as it spreads out from a source. Spreading describes the reduction in sound pressure caused by the increase in surface area as the distance from a sound source increases. Spherical and cylindrical spreading are the simplest forms of spreading loss.

In the simple case of sound propagating from a point source without obstruction or reflection, the sound waves take on the shape of an expanding sphere. An example of spherical spreading loss is shown in Figure D.1-5. As spherical propagation continues, the sound energy is distributed over an ever-larger area following the inverse square law: the pressure of a sound wave decreases inversely with the square of the distance between the source and the receptor. For example, doubling the distance between the receptor and a sound source results in a reduction in the pressure of the sound to one-fourth of its initial value, tripling the distance results in one-ninth of the original pressure, and so on. Because the surface area of a sphere is $4\pi r^2$, where r is the sphere radius, the change in SPL with distance r from the source is proportional to the radius squared. This relationship is known as the spherical spreading law. The TL for spherical spreading between two locations is:

$$TL = 20log_{10}(r)$$

- 2 x distance, 6 dB loss
- 3 x distance, 10 dB loss
- 10 x distance, 20 dB loss

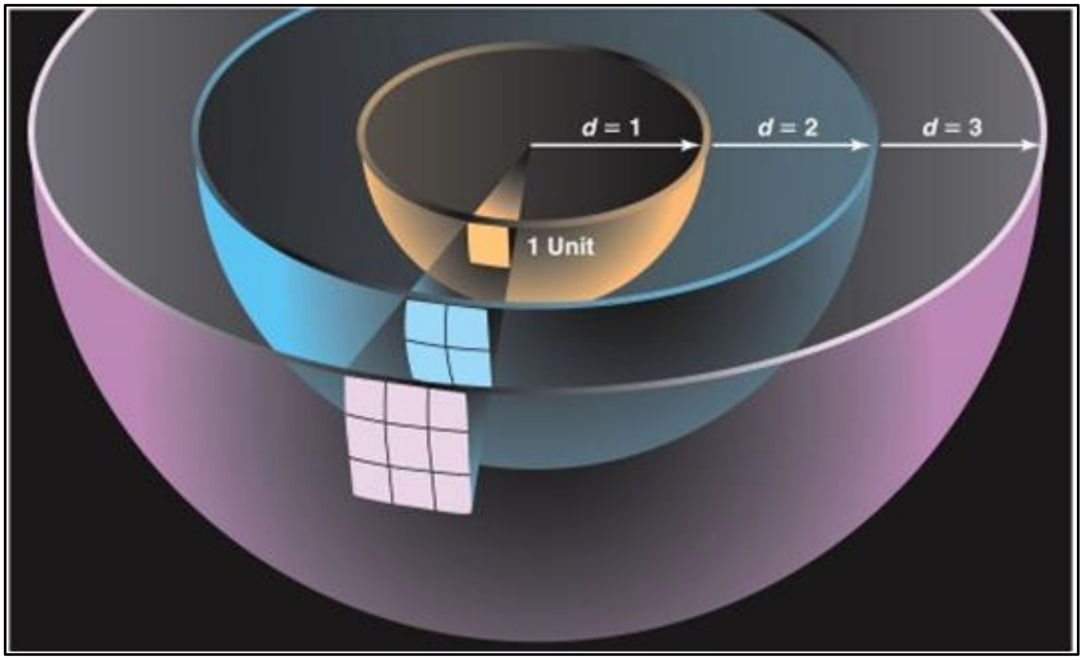


Figure D.1-5: Graphical Representation of the Inverse Square Relationship in Spherical Spreading with Increasing Distance from the Source (d)

In cylindrical spreading, spherical waves expanding from the source are constrained by the water surface and the seafloor and take on a cylindrical shape. In this case the sound wave expands in the shape of a cylinder rather than a sphere, and the transmission loss is:

$$TL = 10log_{10}(r)$$

- 2 x distance, 3 dB loss
- 3 x distance, 5 dB loss
- 10 x distance, 10 dB loss

The cylindrical and spherical spreading equations above represent two simple hypothetical cases. In reality, geometric spreading loss is more spherical near a source and more cylindrical with distance, and is better predicted using more complex models that account for environmental variables, such as the Navy Acoustic Effects Model [see technical report *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing* (U.S. Department of the Navy, 2024b).

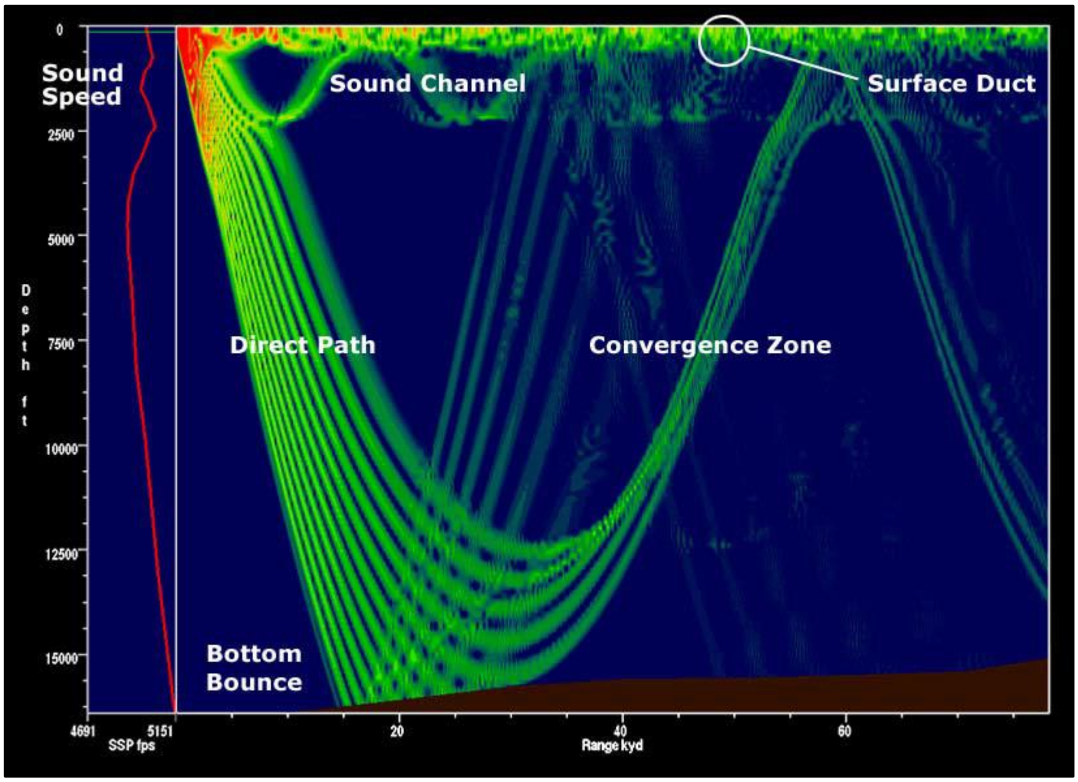
D.1.3.3.2 Absorption

Absorption loss is the conversion of acoustic energy to heat and kinetic energy and occurs when sound propagates through a medium(Urick, 1983). Absorption is directly related to sound frequency, with higher frequencies (>10 kHz) having higher rates of absorption. The main cause of absorption in sea water occurs below 100 kHz and is due to ionic relaxation of dissolved salts (primarily magnesium sulfate). Therefore, absorption is the cause of an appreciable amount of attenuation for high- and very high-frequency sound sources, reducing the distance over which these sources may be perceived compared to mid- and low-frequency sound sources with the same source level.

D.1.3.3.3 Refraction

When a sound wave propagating in a medium encounters a second medium with a different density (e.g., the air-water boundary), part of the incident sound will be reflected back into the first medium and part will be transmitted into the second medium (Kinsler et al., 1982). The propagation direction will change as the sound wave enters the second medium; this phenomenon is called refraction. Refraction may also occur within a single medium if the properties (e.g., temperature) of the medium change enough to cause a variation in the sound speed.

As discussed in Section D.1.3.1, Speed of Sound, the sound speed in the ocean primarily depends on hydrostatic pressure (i.e., depth) and temperature. Although the actual variations in sound speed are small, the existence of sound speed gradients in the ocean has an appreciable effect on the propagation of sound in the ocean. If one pictures sound as rays emanating from an underwater source, the propagation of these rays changes as a function of the sound speed profile in the water column. Specifically, the directions of the rays bend toward regions of slower sound speed. This phenomenon creates ducts in which sound becomes “trapped,” allowing it to propagate with high efficiency for large distances within certain depth boundaries. During winter months, the reduced sound speed at the surface due to cooling can create a surface duct that efficiently propagates sound such as commercial shipping noise (Figure D.1-6).



Note: 1 kiloyard (kyd) = 0.9 km

Figure D.1-6: Sound Propagation Showing Multipath Propagation and Conditions for Surface Duct

Sources located within this surface duct can have their sounds trapped, but sources located below this layer would have their sounds refracted downward. The deep sound channel, or sound frequency and ranging (SOFAR) channel is between 600–1,200 m deep at mid-latitudes and is where the slowest sound speed (i.e., sound speed minimum) occurs. The sound speed minimum creates a waveguide where sound waves are continually bent, or refracted, towards the region of lower sound speed which allows sound to travel long distances with minimal attenuation.

Similarly, the path of sound will bend toward regions of lower sound speed in air. Air temperature typically decreases with altitude. Since the speed of sound decreases in cooler temperatures, sounds produced in air tend to bend skyward. When an atmospheric temperature inversion is present, air is cooler near the earth's surface than at altitude. In inversion conditions, sound waves near the earth's surface will tend to refract downward.

D.1.3.3.4 Reflection and Multipath Propagation

In multipath propagation, sound may not only travel a direct path (with no reflection) from a source to a receiver, but also be reflected from the surface or bottom multiple times before reaching the receiver (Urick, 1983). Reflection is shown in Figure D.1-6 at the seafloor (bottom bounce) and at the water surface. At some distances, the reflected wave will be in phase with the direct wave (their waveforms add together and create a convergence zone), and at other distances the two waves will be out of phase (their waveforms cancel). The existence of multiple sound paths, or rays, arriving at a single point can result in multipath interference, a condition that permits the addition and cancellation between sound waves, resulting in the fluctuation of sound levels over short distances.

Reflection plays an important role in the pressures observed at different locations in the water column. Near the bottom, the direct path pressure wave may sum with the bottom-reflected pressure wave, increasing the exposure. Near the surface, however, the surface-reflected pressure wave may destructively interfere with the direct path pressure wave, by "cutting off" the wave and reducing exposure (called the Lloyd mirror effect). This can cause the sound level to decrease dramatically within the top few meters of the water column.

D.1.3.3.5 Diffraction, Scattering, and Reverberation

Diffraction, scattering, and reverberation are examples of what happens when sound waves interact with obstacles in the propagation path.

Diffraction may be thought as the change of direction of a sound wave as it passes around an obstacle. Diffraction depends on the size of the obstacle and the sound frequency. The wavelength of the sound must be larger than the obstacle for notable diffraction to occur. If the obstacle is larger than the wavelength of sound, an acoustic shadow zone will exist behind the obstacle where the sound is unlikely to be detected. Common examples of diffraction include sound heard from a source around the corner of a building and sound propagating through a small gap in an otherwise closed door or window.

An obstacle or inhomogeneity (e.g., smoke, suspended particles, gas bubbles due to waves, and marine life) in the path of a sound wave causes scattering as these inhomogeneities reradiate incident sound in a variety of directions (Urick, 1983). Reverberation refers to the prolongation of a sound, after the source has stopped emitting, caused by multiple reflections at water boundaries (surface and bottom) and scattering.

D.1.3.3.6 Surface and Bottom Effects

Because the sea surface reflects and scatters sound, it has a major effect on the propagation of underwater sound in applications where either the source or receiver is at a shallow depth (Urick, 1983). If the sea surface is smooth, the energy from a reflected sound wave is nearly equal to the energy of an incident (i.e., incoming) sound wave; however, if the sea surface is rough, the amplitude of the reflected sound wave will be reduced. Sound waves in water reflected from a boundary with air (i.e., the sea surface) experience a phase reversal (i.e., a 180° change). When the surface-reflected waves interact with the direct path waves near the surface, a destructive interference pattern is created in which the two waves are out of phase by half a cycle and cancel each other out when added together. As a result, the amplitude of the two waves and the sound pressure become zero.

The sea bottom is also a reflecting and scattering surface, like the sea surface. Sound interaction with the sea bottom is more complex, primarily because the acoustic properties of the sea bottom are more variable, and the bottom is often layered into regions of differing density. As sound travels into the seafloor it reflects off these different density layers in complex ways. For sources in contact with the bottom, such as bottom-placed explosives, a ground wave is produced that travels through the bottom sediment and may refract back into the water column.

Sediment grain size, composition, and the measure of pore space (i.e., porosity) affect sound propagation and attenuation at the sea floor. In addition, sediments contain free or trapped gas and/or organic content which can affect the bulk properties of the sediment. For a hard bottom such as rock, the reflected wave will be approximately in phase with the incident wave. Thus, near the ocean bottom, the incident and reflected sound pressures may add together (constructive interference), resulting in increased sound pressure near the sea bottom. Soft bottoms such as mud or sediment absorb sound waves and reduce the level in the water column overall.

D.1.3.4 Air-Water Interface

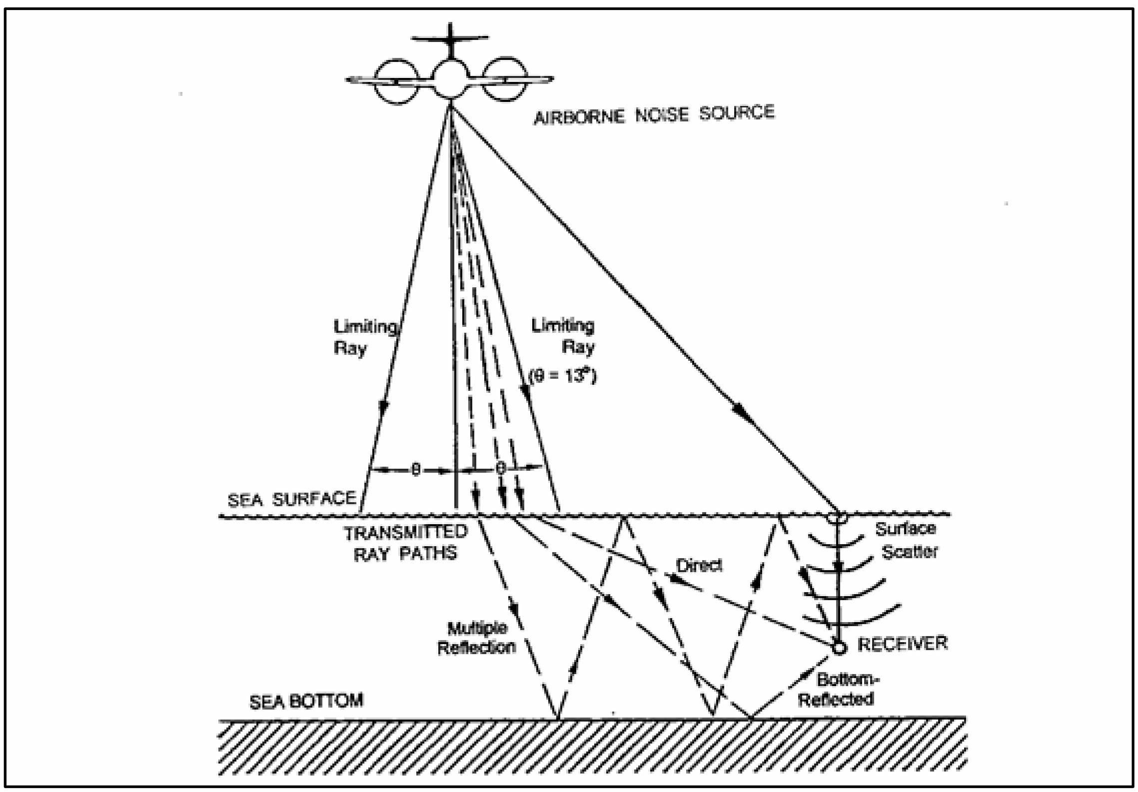
Sound from aerial sources such as aircraft and weapons firing may be transmitted into the water under certain conditions. The most studied of these sources are fixed-wing aircraft and helicopters, which create noise with most energy below 500 Hz. Underwater noise levels are highest at the surface and are highly dependent on the altitude of the aircraft, the angle at which the aerial sound encounters the water surface, and the amount of wave action and surface roughness. Transmission of the sound once it is in the water is identical to any other sound as described in the sections above.

Transmission of sound from a moving, airborne source to a receptor underwater is influenced by numerous factors and has been addressed by Young (1973), Urick (1983), Richardson et al. (1995b), Eller and Cavanagh (2000), U.S. Department of the Air Force (2000), and others. Sound is transmitted from an airborne source to a receptor underwater by four principal means: (1) a direct path, refracted upon passing through the air-water interface; (2) direct-refracted paths reflected from the bottom in shallow water; (3) evanescent transmission in which sound travels laterally close to the water surface; and (4) scattering from interface roughness due to wave motion.

At the air-water interface, sound can either be transmitted across the air-water boundary or reflected off the water surface. When sound waves meet the water at a perpendicular angle (e.g., straight down from an in-air source to a flat-water surface), the sound waves are both transmitted directly across the water surface in the same direction of travel and reflected 180 degrees back toward the original direction of travel. This can create a localized condition at the water surface where the incident and reflected waves sum, resulting in constructive interference, and doubling the in-air overpressure (+ 6 dB). As the incident angle of the in-air sound wave changes from perpendicular, this phenomenon is reduced, ultimately reaching the angle where sound waves are parallel to the water surface and there is no surface reflection.

The sound that enters the water is refracted due to the difference in sound velocity between air and water, as shown in Figure D.1-7. As the angle of the in-air incident wave moves away from perpendicular, the direction of travel of the underwater refracted waves becomes closer to parallel to the water surface. When the incident angle is reached, the underwater refracted sound wave is parallel to the water surface and all the sound is reflected into the air and no sound enters the water. This occurs at an angle of about 13 to 14 degrees. As a result, most of the acoustic energy is transmitted into the water through a relatively narrow cone extending vertically downward from the in-air source. The width of the footprint would be a function of the source altitude. Lesser amounts of sound may enter the water outside of this cone due to surface scattering (e.g., from water surface waves that can vary the angle of incidence over an area) and as evanescent waves that are only present very near the surface.

If a sound wave is ideally transmitted into water (that is, with no surface transmission loss, due to foamy, wave conditions that could decrease sound entering the water), the SPL underwater is calculated by changing the pressure reference unit from 20 µPa in air to 1 µPa in water. For a sound with the same pressure in air and water, this calculation results in a +26 dB SPL in water compared to air. Sounds of equal intensity, however, will be 62 dB higher in water than in air. This is due not only to the difference in reference pressures, but also differences in impedance. For this reason, sound measurements in water and in air cannot be directly compared.



Source: (Richardson et al., 1995b)

Figure D.1-7: Characteristics of Sound Transmission Through the Air–Water Interface

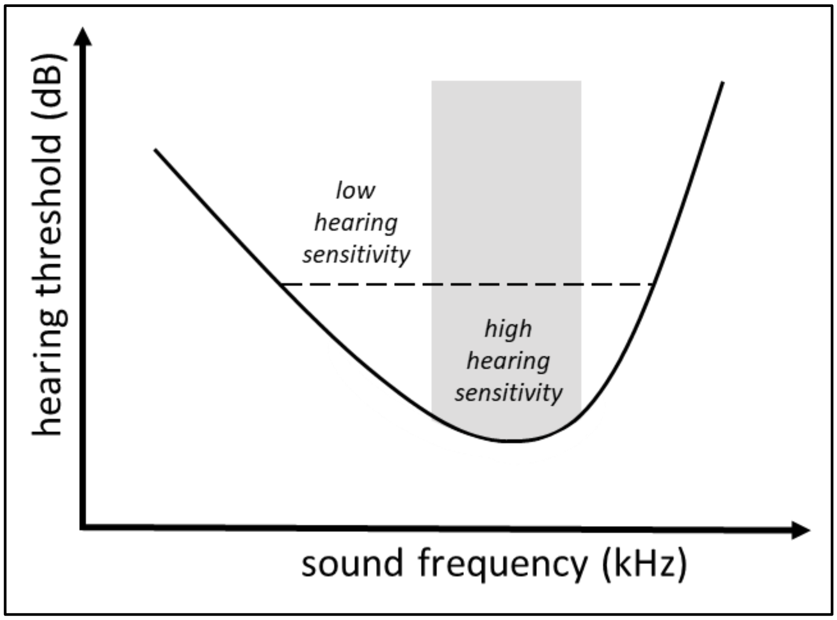
D.1.4 AUDITORY PERCEPTION

Animals with an eardrum or similar structure, including mammals, birds, and reptiles, detect the pressure component of sound. Some marine fishes also have specializations to detect pressure changes, although most invertebrates and many marine fishes do not have anatomical structures that enable them to detect the pressure component of sound and are only sensitive to the particle motion component of sound. This difference in acoustic energy sensing mechanisms limits the range at which fishes and invertebrates can detect most sound sources.

Because mammalian ears can detect large pressure ranges and humans judge the relative loudness of sounds by the ratio of the sound pressures (a logarithmic behavior), sound amplitude is described by the SPL, calculated by taking the logarithm of the ratio of the sound pressure to a reference pressure (see Section D.1.2.2, Sound Pressure Level). Use of a logarithmic scale compresses the wide range of pressure values into a more usable numerical scale. On the decibel scale, the smallest audible sound in air (near total silence) to a human is 0 dB re 20 µPa. If the sound intensity increases by a factor of 10, the SPL would increase to 10 dB re 20 µPa. If the sound intensity increases by a factor of 100, the SPL would increase to 20 dB re 20 µPa, and if the sound intensity increases by a factor of 1000, the SPL would be 30 dB re 20 µPa. A quiet conversation has an SPL of about 50 dB re 20 µPa, while a jet engine taking off 200 ft away is about 130 dB re 20 µPa (Cavanaugh & Tocci, 1998).

While sound pressure and frequency are physical measures of the sound, loudness is a subjective attribute that varies not only with sound pressure but also other attributes of the sound, such as frequency. For example, a human listener would perceive a 60 dB re 20 µPa sound at 2 kHz to be louder than a 60 dB re 20 µPa sound at 50 Hz, even though the SPLs are identical. This effect is most noticeable at lower SPLs; however, at very high SPLs, the difference in perceived loudness at different frequencies becomes smaller. This difference in perception for sounds having the same SPLs but different frequencies is related to the hearing capabilities of the individual or species.

The most accurate tests for determining the hearing capabilities of animals are direct measurements of auditory sensitivity. The two standard types of hearing tests are: 1) behavioral, where an animal is trained to provide a response to sound, and 2) physiological, where – without any training – the brain's responses to sound are measured (auditory-evoked potentials, or AEPs) (Finneran, 2015). During these tests, the sound is played at progressively lower levels until the animal can no longer hear it or until the brain's responses are no longer detected, and the hearing threshold in dB SPL is determined. The hearing threshold is the quietest audible sound, so a low hearing threshold indicates more sensitive hearing. When multiple frequencies are tested across the hearing range of an animal, a plot called an audiogram illustrates how hearing threshold changes as a function of sound frequency. An example of an audiogram is shown in Figure D.1-8.



Notes: (dB = decibels; kHz = kilohertz) The area within the solid curve represents audible sounds. The dotted line illustrates that the listener is not as sensitive to frequencies on the tail ends of the curve as the frequencies that align with the bottom of the "U." The shaded area is the frequency range with the lowest thresholds and highest hearing sensitivity, also called the region of best hearing. Marine mammal auditory sensitivity typically decreases more slowly at frequencies lower than the best frequency and decreases more quickly for frequencies higher than the best frequency.

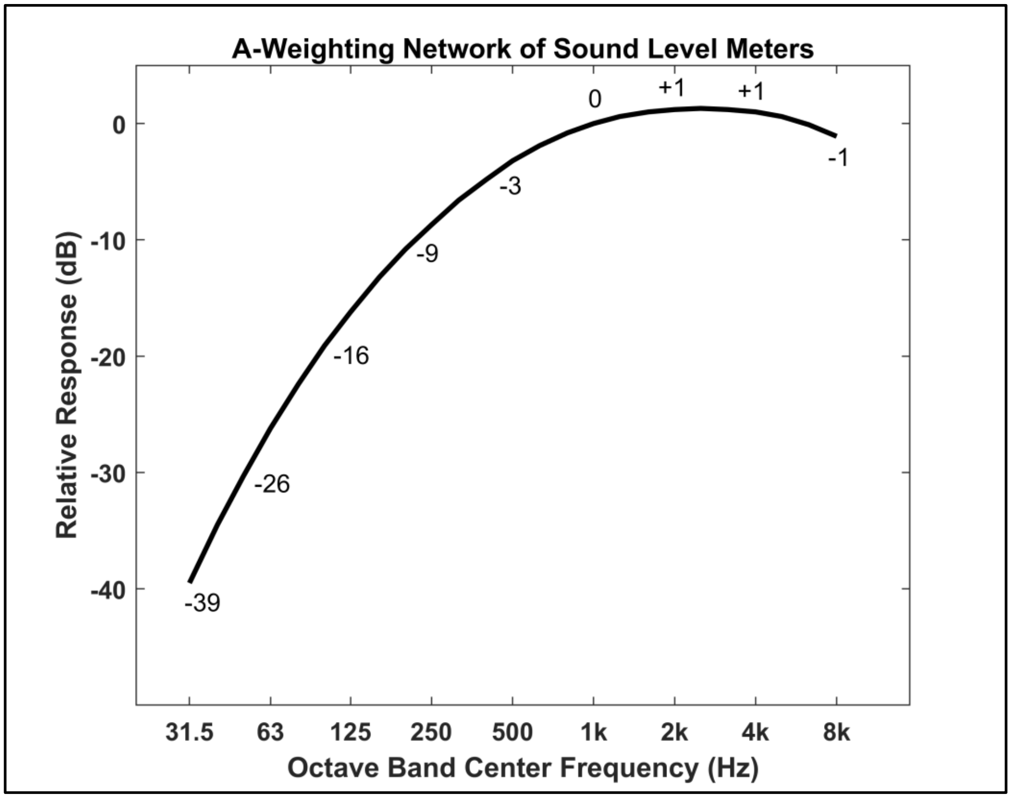
Figure D.1-8: Example of an Audiogram

To account for differences in hearing sensitivity at various frequencies, acoustic risk analyses commonly use auditory weighting functions—mathematical functions that adjust (or "weight") received sound levels with frequency based on how the listener's sensitivity or susceptibility to sound changes at different frequencies. For humans, the most common weighting function is called "A-weighting" (see Figure D.1-9). A-weighted sound levels are specified in units of "dBA" (A-weighted decibels). For example, if the unweighted received level of a 500 Hz tone at a human receiver was 90 dB re 20 µPa, the A-weighted sound level would be 90 dB – 3 dB = 87 dBA because the A-weighting function amplitude at 500 Hz is -3 dB (Figure D.1-9. Many measurements of sound in air appear as A-weighted decibels in the literature because the intent of the authors is to assess noise impacts on humans.

The auditory weighting concept can be applied to other species. When used in analyzing the impacts of sound on an animal, auditory weighting functions adjust received sound levels to emphasize ranges of best hearing and de-emphasize ranges of less or no sensitivity. Auditory weighting functions were developed for marine mammals and sea turtles and are used to assess acoustic impacts. Additional information on auditory weighting functions and their derivation for this analysis are described in the *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase IV) technical report* (U.S. Department of the Navy, 2024a).

Masking occurs when noise interferes with the detection, discrimination, or recognition of the relevant sound or signal (Erbe et al., 2016). Auditory masking is defined as the amount in dB by which the threshold of hearing for one sound is raised by the presence of a masking sound (Acoustical Society of

America, 2015). Masking occurs only in the presence of the masking noise and does not persist after the cessation of the noise.



Notes: (dB = decibels; Hz = hertz) The numbers along the curve indicate how a received sound level would be adjusted at that frequency.

Figure D.1-9: A-Weighting for Human Hearing of Sounds in Air (adapted from OSHA)

D.1.5 Acoustic Propagation in Small Tanks

Although it is common to conduct bioacoustic research in small tanks with fishes, invertebrates, and other taxa, results from such experiments should be considered with caution due to the complicated acoustic fields that exist within small tank environments (Akamatsu et al., 2002). In a natural environment such as the open ocean, the particle velocity component of a signal contains more energy closer to the source (i.e., in the near field) compared to sound pressure. As sound propagates away from the source, this relationship shifts into a linear one as the two decay at the same rate in the far field. In a small tank, the acoustic field is complicated by boundaries, specifically the air-water interface at the walls and floor of the tank, and at the water surface (Akamatsu et al., 2002). These boundaries cause multiple overlapping reflections that alter the relationship between particle motion and sound pressure in the near field, attenuate the low-frequency components of the sound, and distort the directionality of the signal. As described in Section D.1.1.8, Resonance, it is known that small containers have resonant frequencies depending on their physical dimensions. When the acoustic signal used in an experiment overlaps that of the tank's resonant frequency, the sound is further distorted. Additionally, the physical dimensions of small tanks can be shorter than the wavelength of the signal used in bioacoustic experiments, further complicating the potential received signal. The placement of the sound source is also an important consideration as there is evidence that the source characteristics may vary at the receiver depending on whether the transducer is located in-water (within the tank) or in-air (adjacent to the tank) (Rogers et al., 2016). It is important for laboratory tests in small tanks to properly measure and characterize the sound field considering reverberations and refractions off the boundaries of the tank (Takahashi & Akamatsu, 2018), as well as the test subject itself (especially when using animals that contain air filled organs). In the absence of such considerations, experiments conducted in small tanks may overestimate or mischaracterize the results.

D.1.6 Explosives

Explosive materials used in Navy military readiness activities are either (1) high explosives (HE) material has a fast rate of detonation (exceeding the speed of sound), or (2) low explosives, which exhibit a relatively slow burn, or deflagration, such as black powder. Because low explosives are typically used in small quantities and have less destructive power, the below discussion focuses on high explosives.

The rate of detonation of a high explosive is supersonic and instantaneous, producing a steep, high-pressure shock wave that travels forward through explosive material. This shock front is produced by the supersonic expansion of the explosive products, but as the shock front travels away from the immediate area of the detonation, it begins to behave as an acoustic wave front travelling at the speed of sound.

The near-instantaneous rise from ambient to an extremely high peak pressure is what makes the explosive shock wave potentially damaging. Explosive exposures are usually characterized by the metrics of impulse and peak pressure. The positive impulse is calculated by integrating the positive pressure over the duration of the positive phase. The positive pressure produced by an explosion is also referred to as overpressure. As the shock front passes a location, the positive pressure exponentially decays, as shown in Figure D.1-10. As the shock front travels away from the detonation, the waveform is stretched—the peak pressure decreases while the positive duration increases. Both the reduction in peak pressure and stretching of the positive impulse reduce the potential for injury. In addition, absorption losses of higher frequencies over distance results in a softening of the shock front, such that the rise to peak pressure is no longer near instantaneous.

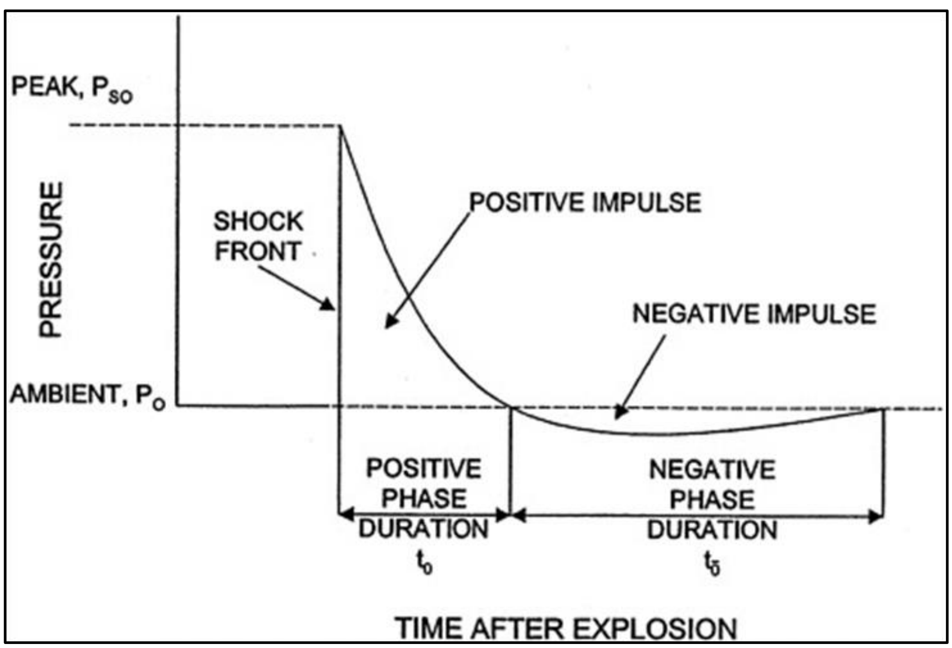


Figure D.1-10: Impulse Shown as a Function of Pressure over Duration at a Specific Location

The peak pressure experienced by a receptor (i.e., an animal) is a function of the explosive material, the net explosive weight (NEW), and the distance from the charge. NEW is a way to classify and compare quantities of different explosive compounds. The NEW for a given charge is the energetic equivalent weight of trinitrotoluene (TNT). In general, shock wave effects near an explosive charge increase in proportion to the cube root of the explosive weight (Young, 1991). For example, shock wave impacts will double when the explosive charge weight is increased by a factor of eight (i.e., cube root of eight equals two). This cube root scaling relationship is known as the similarity principle and allows for a simple prediction of peak pressure in a uniform free field environment to estimate explosive effects in air and in water. However, at longer distances or in more complex environments with boundaries and variations in the propagation medium, explosive propagation modeling is preferred.

D.1.6.1 Explosions in Air

Pressure waves from explosions in air interact with the air-water boundary as previously described under Section D.1.3.4, Air-Water Interface. In certain explosive geometries, depending on the size of the explosive and its height of detonation, a combined shock wave, called a Mach stem, can be created when direct and reflected shock waves merge and form a single wave (Kinney & Graham, 1985). In instances where this specific geometry does not occur, only the direct path wave is experienced because there is no surface reflection (waves are parallel to or angled away from the water surface, such as would occur when an explosive is detonated at the water surface), or separate direct and reflected pressure waves may be experienced.

D.1.6.2 Explosions in Water

At the instant of explosion underwater, gas byproducts are generated at high pressure and temperature, creating a bubble. The heat causes a certain amount of water to vaporize, adding to the volume of the bubble. This action immediately begins to force the water in contact with the blast front in an outward direction, creating an intense, supersonic-pressure shock wave. As the high-pressure wave travels away from the source, it slows to the speed of sound and acts like an acoustic wave like other impulsive sources that lack a strong shock wave. Explosions have the greatest amount of energy at frequencies below 500 Hz, although energy is present at frequencies exceeding 10 kHz (Urick, 1983). The higher frequency components exhibit more attenuation with distance due to absorption (see Section D.1.3.3.2, Absorption).

The shock wave caused by an explosion in deeper water may be followed by several bubble pulses in which the explosive byproduct gases expand and contract, with correlated high- and low-pressure oscillations. These bubble pulses lack the steep pressure front of the initial explosive pulse, but the first bubble pulse may still contribute to the total energy released at frequencies below 100 Hz (Urick, 1983). Subsequent bubble pulses contribute little to the total energy released during the explosion (Urick, 1983). If the detonation occurs at or just below the water surface, a portion of the explosive power is released into the air and a pulsating gas bubble is not formed.

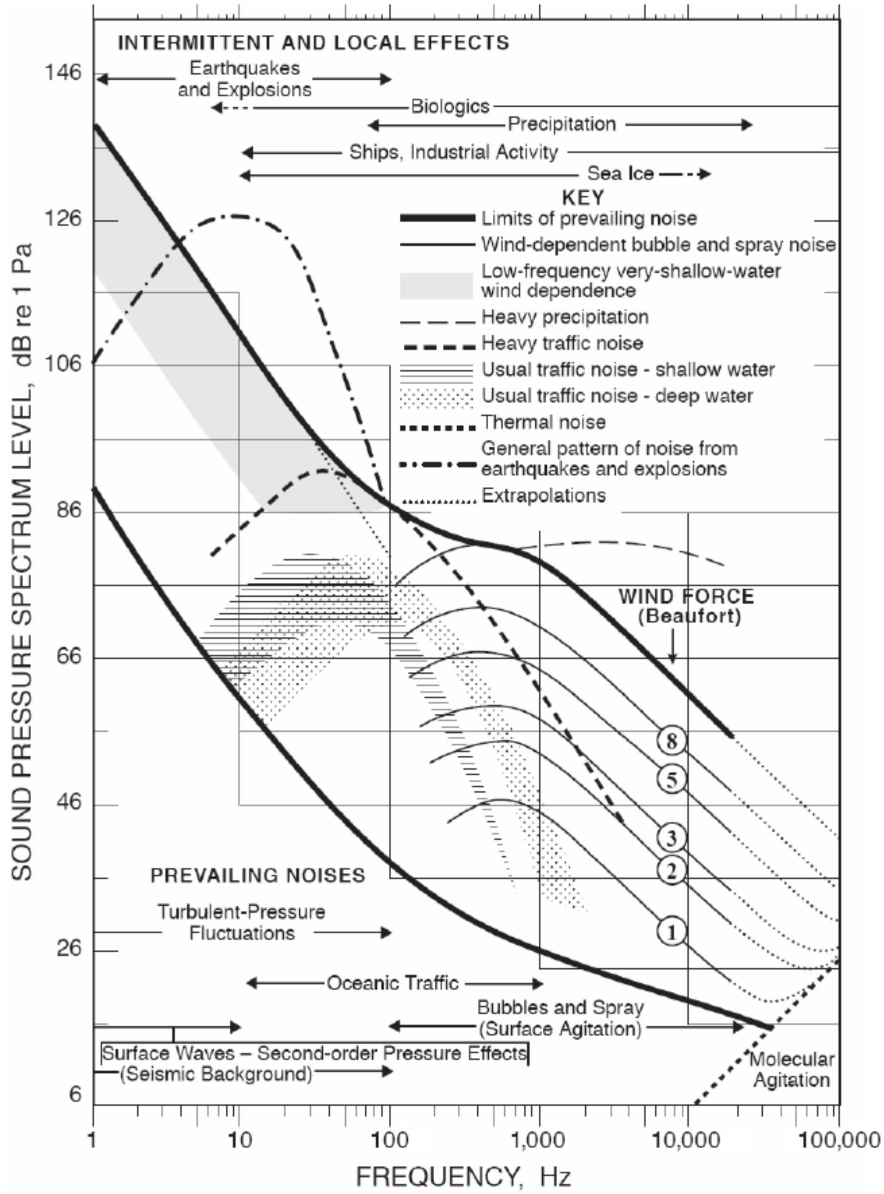
The pressure waves from an explosive can constructively add or destructively cancel each other in ocean environments with multi-path propagation, as described for acoustic waves in Sections D.1.3.3.3, Refraction, and D.1.3.3.4, Reflection and Multipath Propagation. The received impulse is affected by the depth of the charge and the depth of the receiving animal. Pressure waves from the detonation may travel directly to the receiver or interact with the water surface or sea floor before arriving at the receiver. If a charge is detonated closer to the surface or if an animal is closer to the surface, the time between the initial direct path arrival and the following surface-reflected tension wave arrival is reduced, resulting in a steep negative pressure cut-off of the initial direct path positive impulse exposure. Two animals at similar distances from a charge, therefore, may experience the same peak pressure but different levels of impulse at different depths.

D.2 Acoustic Habitat

Ambient noise is defined as encompassing all noise at a specific location and time in the absence of a specified sound (International Organization for Standardization, 2017). Ambient noise is continuous and has considerable variation across time and space, varying by as much as 10–20 dB from day to day (Richardson et al., 1995b). The first systematic investigation of ambient noise was performed by Knudsen et al. (1948) and examined the relationship between noise level, wind speed, and sea state. Wenz (1962) expanded on the work by Knudsen et al. (1948) and described the spectra of natural and anthropogenic sources that contribute to noise in the ocean (Figure D.2-1). In general, the ambient noise spectrum can be broadly categorized into three frequency bands (Wenz, 1962). The low-frequency band (10-500 Hz) is dominated by shipping noise, the mid-frequency band (500 Hz-25 kHz) is governed by surface agitation from wind and weather, and the high-frequency band (greater than 25 kHz) is influenced by thermal noise from molecular agitation of water molecules (particularly greater than 50 kHz). Despite changes in the ocean environment, the Knudsen Curves and Wenz Curves are still applicable and useful for understanding and estimating noise levels.

D.2.1 Natural Noise

In underwater soundscape ecology, naturally occurring noise is categorized as geophony, which includes natural sounds of the earth (e.g., wind, waves, and earthquakes), and biophony, which includes sounds from living organisms (e.g., whales, fish, and snapping shrimp). Anthropophony (human generated signals) are not considered part of natural environmental noise. In the absence of distant shipping noise, natural sources dominate the long-term, time-averaged ocean noise across all frequencies. When distant shipping noise is present, natural sources continue to dominate time-averaged ocean noise spectra below 5 Hz and from around 500 Hz to over 200 kHz (National Research Council, 2003; Wenz, 1962). Prevalent sources of naturally occurring noise discussed in this section are generated by processes including wind, waves, rain, earthquakes, volcanoes, thermal noise, and biological sources.



Source: Wenz (1962)
Note: Hz = hertz; dB re 1 µPa = decibels with a reference of 1 micropascal (µPa)

Figure D.2-1: Wenz Curves Describing the Spectra of Ambient Ocean Noise

D.2.1.1 Surface Interactions

Prevailing ambient noise associated with wind, waves, and rain has multiple contributing factors across a broad frequency range from below 1 Hz to at least 50 kHz (Figure D.2-1). Between 500 Hz and 25 kHz, ambient noise is governed by wind speed, sea state, and resulting surface agitation including air bubble cavitation and spray. At frequencies lower than 500 Hz, ambient noise is less correlated with wind speed and sea state, and as low as 50-100 Hz no relationship exists (Wenz, 1962). Noise from shipping and other anthropogenic activities become the prevalent sources of ambient noise at frequencies lower than 500 Hz and it is difficult to discern the impact of wind related noise at lower frequencies (Wenz, 1962). The wind-generated noise spectra for a given sea state (i.e., Beaufort 1, 2, 3, 5, and 8 in Figure D.2-1) have a slope of

-5 dB/octave (e.g., a loss of 5 dB of sound energy for each doubled frequency range) or -18 dB/decade (e.g., a loss of 18 dB of sound energy for each tenfold frequency range) and a -29 dB in the spectra from 500 Hz to 25 kHz (Knudsen et al., 1948). Cavitating air bubbles that form near the surface and grow due to a process called rectified diffusion from pressure changes caused by waves, contribute to overall noise levels when bubbles collapse. Whitecaps and spray at the surface can increase estimated noise levels for a given Beaufort sea state in Figure D.2-1 by 4-5 dB when conditions are unusually windy, such as during a large storm (Knudsen et al., 1948). In contrast, estimated noise levels for a given Beaufort sea state may be lower than those in Figure D.2-1 when there is reduced spray and calm conditions.

At frequencies below 10 Hz, surface gravity wave interactions create pressure fluctuations. First order pressure effects are due to the elevation and movement of water at the surface and causes subsurface pressure fluctuations below 0.3 Hz at less than 100 m depth (Wenz, 1962). Second order pressure effects occur when two surface waves with the same wavelength travel in opposite directions (e.g., from being reflected offshore). This magnifies the crests and troughs and form a standing wave with consistent pressure across depth, and a frequency twice that of the two surface waves. The noise spectrum of a standing wave has a slope of -8 to -10 dB/octave in the frequency range from 1 to 10 Hz (Wenz, 1962).

Intermittent ambient noise from rain is affected by the rate of rainfall, droplet size, wind speed, and area covered. Together, these factors contribute to noise levels primarily above 500 Hz, however, noise levels can extend to lower frequencies (e.g., if heavy rainfall occurs with low wind speeds) (Wenz, 1962). Underwater noise from rainfall is generated by the impact of droplets on the water surface, and by trapping a bubble underwater during a splash (Nystuen, 2001). Rain droplet size affects the underwater sound spectrum. Small droplets (0.8–1.2-millimieter [mm] diameter) have a strong signal in the spectrum from 13-25 kHz; medium droplets (1.2–2.0 mm diameter) have a signal from 1-30 kHz; large droplets (2.0–3.5-mm diameter) have a signal from 1-35 kHz with a peak in the spectrum at 2-5 kHz, and very large droplets (greater than 3.5-mm diameter) have a signal from 1-50 kHz with a peak in the spectrum from 1-2 kHz (Nystuen, 2001). During light rainfall, the ambient noise level can increase by 10-20 dB around 15 kHz (Nystuen & Farmer, 1987). In the 1-50 kHz range, heavy rainfall can increase the noise level up to 35 dB, and during extreme rainfall events (rate greater than 100 mm/hour) the noise level can increase up to 50 dB (Nystuen, 2001).

D.2.1.2 Biological Sources

Biological sources with an appreciable contribution to underwater ambient noise levels are briefly summarized here. Additional details on sounds from biological sources are provided in the sections below.

Marine mammal vocalizations cover a wide frequency range from less than 10 Hz to around 200 kHz. Broadband clicks and burst pulse signals produced by odontocetes can be used for echolocation, navigation, prey capture, and communication and have peak energy between approximately 10 and 150 kHz. Odontocetes also produce whistles for communication with fundamental frequencies between approximately 1 and 50 kHz. Vocalizations from mysticetes are lower frequency, from tens of Hertz to typically less than 10 kHz, and have the potential to be detected over long distances. For example, low-frequency blue whale calls can be heard by other whales up to 1,600 km away. An exception are humpback whales which can produce calls over 10 kHz (Zoidis et al., 2008) with harmonics up to 24 kHz (Au et al., 2006). Calls from mysticetes are diverse and complex in composition and are used for breeding, feeding, navigation, and communication. Depending on the timing and location, marine mammal vocalizations can be the dominant source of underwater noise in a region. For example, vocalizations produced by migrating mysticetes can seasonally increase ambient noise levels an average of 2-9 dB and up to 25 dB in the 15-22 Hz band (Curtis et al., 1999).

Many species of fish produce pulsed signals with most energy below 1 kHz for communication, courtship, mating, aggressive interactions, and when in distress (National Research Council, 2003). The occurrence of fish sounds can also exhibit diurnal, lunar, seasonal, and annual temporal variability. Sounds are produced by individuals, and collectively, many individuals produce choruses which can cause a sustained increase of 10-30 dB in ambient noise levels under 3 kHz (Cato, 1978; D'Spain & Batchelor, 2006).

Sounds from marine invertebrates are prolific in bays, harbors, estuaries, and coastal areas, and can be a major source of biological noise. Snapping shrimp produce high intensity, broadband impulses to communicate, deter predators, and stun prey. Sounds they produce have peak energy from 2-5 kHz with spectral components up to 250 kHz (Au & Banks, 1998) and can increase ambient noise levels up to 20 dB (Hildebrand, 2009). They occur in large aggregations in shrimp beds and are prevalent year-round in shallow and warm waters between +/- 40 degrees latitude (Knudsen et al., 1948). Snap rates are positively correlated with water temperature, and noise levels can vary up to 15 dB in the 1.5-20 kHz frequency band between winter and summer (Bohnenstiehl et al., 2015). Although sounds from snapping shrimp are the most prevalent, other marine invertebrates generate sounds as well. For example, sea urchins generate a scraping sound during feeding from 800 to 2,800 Hz (Radford et al., 2008), and spiny lobsters generate broadband pulses called “antennal rasps”, potentially for intra-specific communication, with most energy below 1 kHz (Jezequel et al., 2022).

D.2.1.3 Geologic Activity

Geologic activity primarily contributes to ocean noise at frequencies less than 100 Hz. Earthquake generated acoustic waves in the ocean are called T-waves (tertiary waves) and produce intermittent sound at low frequencies. Earthquakes can occur under the ocean floor, or originate on land, and propagate between the land and ocean interface. Small earthquakes are more frequent and almost continuous in seismically active regions (e.g., the Mid-Atlantic Ridge and the East Pacific Rise). Recordings of earthquakes at the Mid-Atlantic Ridge have an estimated average source level between 199 and 234 dB re 1 µPa (Williams et al., 2006a), and a 20 dB increase in the ambient noise level has been observed in the 5-32 Hz band (McGrath, 1976). Active underwater volcanoes also generate low-frequency noise with most energy in the octave band centered near 10 Hz (Northrop, 1974).

D.2.1.4 Thermal Noise

Thermal noise is generated by pressure fluctuations from the thermal agitation (the movement of molecules due to energy transference) of water molecules. It is the remaining noise when all other sources are removed and provides a threshold on the minimum observable noise levels in the ocean. Thermal noise dictates the shape and level of ambient noise spectra above 50-100 kHz and causes an increase in ambient noise levels at rate of 6 dB/octave (Urick, 1983).

D.2.2 Anthropogenic Noise

Marine species have existed, evolved, and adapted in the presence of naturally occurring noise for millions of years whereas the presence of anthropogenic noise is relatively recent, has intensified in the past century, and caused widespread alterations to the acoustic habitat (Duarte et al., 2021). Noise from human activities is often dynamic and few sources (e.g., shipping) have consistent inputs to the acoustic habitat. Anthropogenic noise varies widely in terms of frequency range, duration, and loudness and can have short-term and localized effects on acoustic habitats, as well as long-term effects over large areas.

These characteristics strongly influence any potential impacts on marine species and their acoustic habitats. Prevalent sources of anthropogenic noise discussed in this section include vessel noise, sonar, explosions, and industrial activities.

D.2.2.1 Vessel Noise

Vessel noise is a major contributor to noise in the ocean. Radiated noise from ships varies depending on the size, hull design, type of propulsion, and speed. Ship-radiated noise increases with speed and primarily includes propeller blade tip and sheet cavitation (i.e., low pressure vortices shed by blade tips, and a sheet of bubbles on the back of the blade respectively), and broadband noise from water flowing across the hull (Richardson et al., 1995b; Urick, 1983). Based on these factors, vessel noise can contribute to ocean noise from 10 Hz to 10 kHz (Wenz, 1962). Different classes of vessels have unique acoustic signatures characterized by variances in dominant frequencies. Bulk carrier noise is predominantly near 100 Hz while container ship and tanker noise are predominantly below 40 Hz (McKenna et al., 2012). In comparison, small craft emit higher-frequency noise between 1 kHz and 5 kHz (Hildebrand, 2009).

Globally, commercial shipping is not uniformly distributed. Major shipping lanes typically follow great circle routes or coastlines and go to and from dozens of major ports, and hundreds of small harbors and ports. Most recreational boating occurs in shallow coastal waters whereas military, fishing, and scientific research vessels can be widely distributed (National Research Council, 2003).

Vessel traffic patterns in the study area were analyzed by Starcovic and Mintz (2021). The following results illustrate the distribution (Figure D.2-2 to Figure D.2-5) and a statistical summary (Table D.2-1) of the number of vessel transits that occurred within the respective Hawaii and California portions of the Study Area from 2014 to 2018.

In Hawaii, Starcovic and Mintz (2021) show that cargo, bulk carrier, and tanker traffic dominate much of the offshore areas with trans-Pacific routes north and south of the Hawaiian Islands (Figure D.2-2). The geographic distribution of highest military vessel activity is south of Pearl Harbor (Figure D.2-3) with clear routes to the east (to and from San Diego), west (to/from the Marianas Island Training and Testing area) and northwest (to/from Japan). The waters surrounding the Northwestern Hawaiian Islands (which are part of the protected Papahānaumokuākea Marine National Monument) are rarely traversed by non-military or military vessels, other than non-military research vessels.

In Southern California, Starcovic and Mintz (2021) show that cargo, bulk carrier, and tanker traffic dominate north-south shipping lanes along the California and Mexico coasts including routes to/from Japan, Panama Canal, and South America, and between the Ports of Long Beach and Los Angeles (Figure D.2-4). The geographic distribution of highest military vessel activity occurs around San Diego and roughly within 50 NM of shore (Figure D.2-5). Clear routes are seen to the west (to and from Pearl Harbor), and north along the coast (to/from the bases and operating areas in the Pacific Northwest).

Commercial traffic (and, therefore, broadband noise generated by it) is relatively steady throughout the year whereas Navy traffic occurs intermittently and is variable in duration. Within the Study Area, Navy vessels represent 3.5 percent of overall vessel traffic (Table D.2-1), with remaining vessel traffic broken down by non-military vessel class in Table D.2-1. In terms of anthropogenic noise, Navy ships are engineered to be as quiet as possible given ship class limitations, and would contribute a correspondingly smaller amount of shipping noise compared to more common commercial shipping and boating (Mintz, 2012; Mintz & Filadelfo, 2011).

Table D.2-1: Overall Vessel Traffic in the Study Area.

Vessel Class	*% of Traffic*
Tugs	8.2%
Cargo	29.5%
Other	3.6%
Fishing	6.2%
Tanker	14.7%
Bulk Carriers	18.5%
Passenger	10.2%
Service	3.8%
Research	0.9%
U.S. Navy	3.5%
U.S. Coast Guard	0.4%

Source: Starcovic and Mintz (2021)
Notes: % = percent

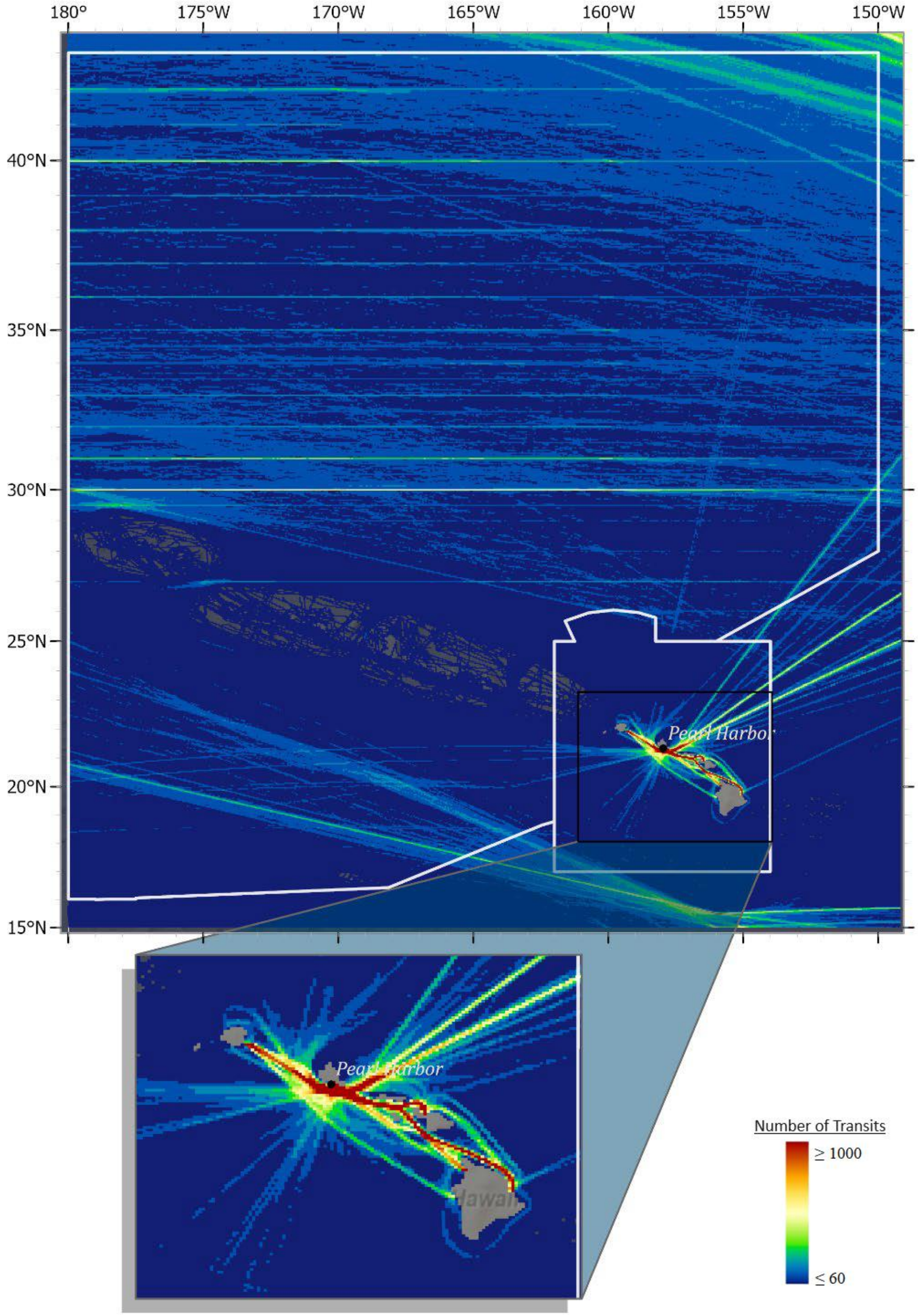


Figure D.2-2: Intensity of Non-military Vessel Traffic in the Hawaii Portion of the Study Area From 2014 to 2018. Source: Starcovic and Mintz (2021).

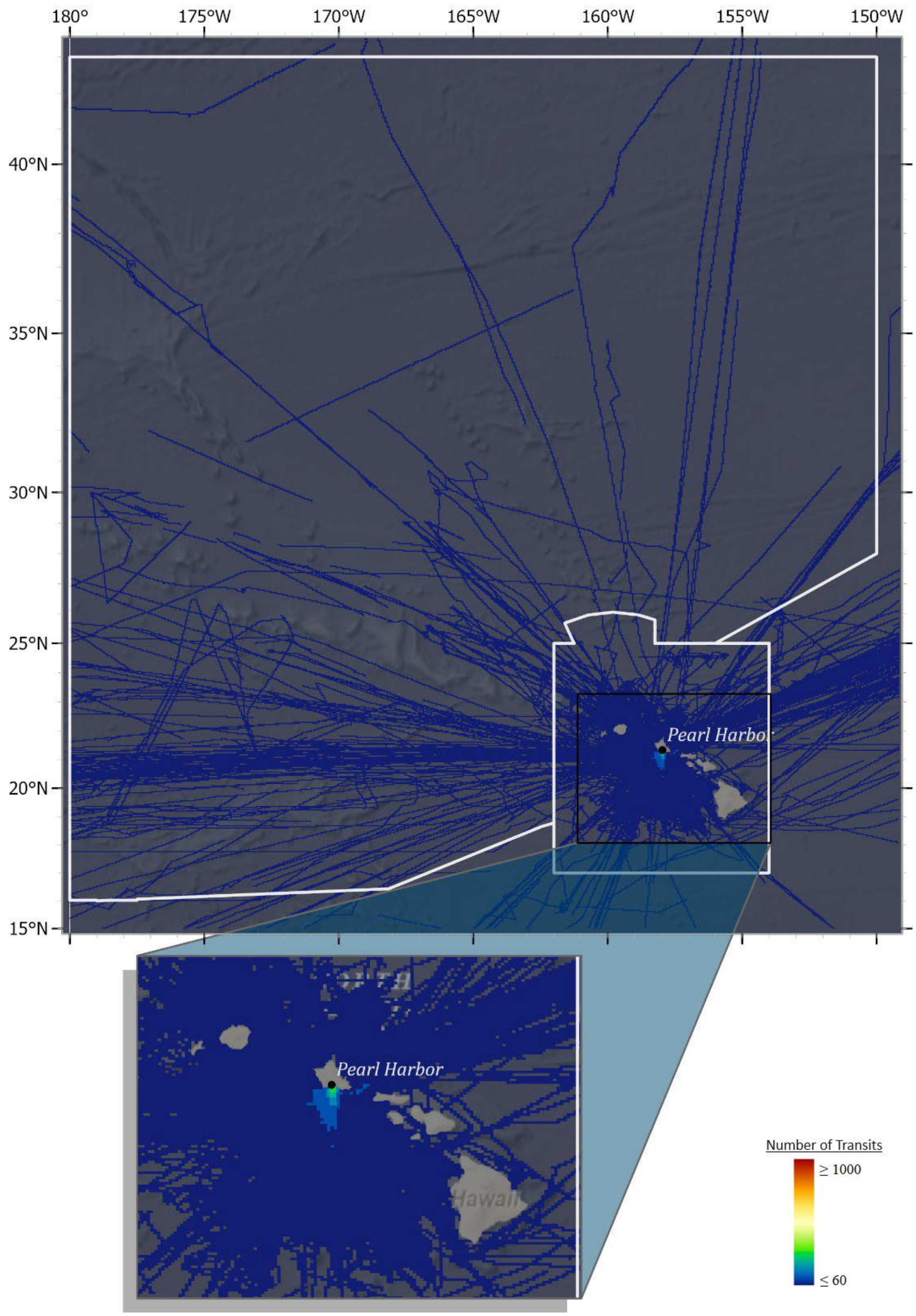


Figure D.2-3: Intensity of military vessel traffic in the Hawaii portion of the Study Area from 2014 to 2018. Source: Starcovic and Mintz (2021).

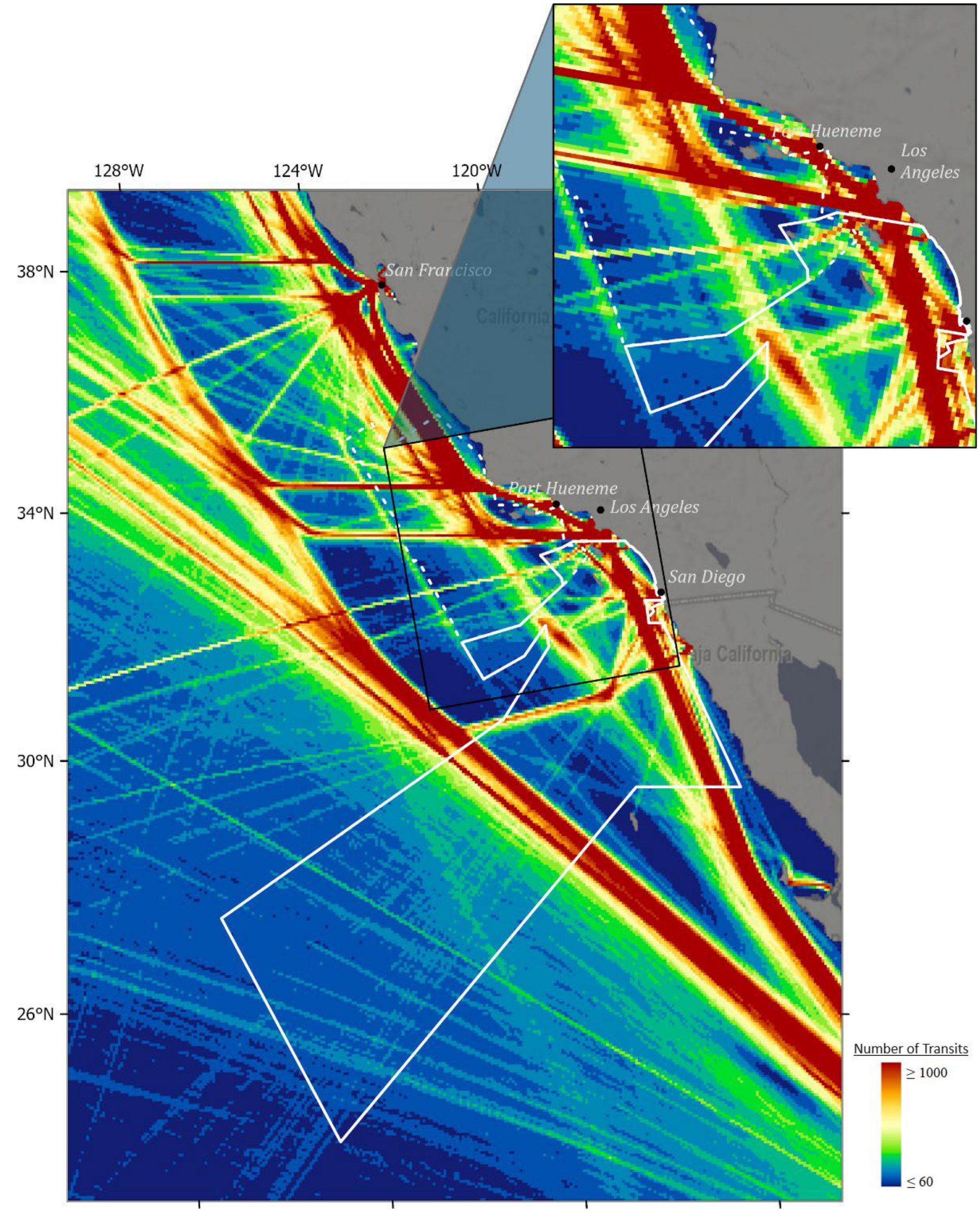


Figure D.2-4: Intensity of non-military vessel traffic in the California portion of the Study Area from 2014 to 2018. Source: Starcovic and Mintz (2021).

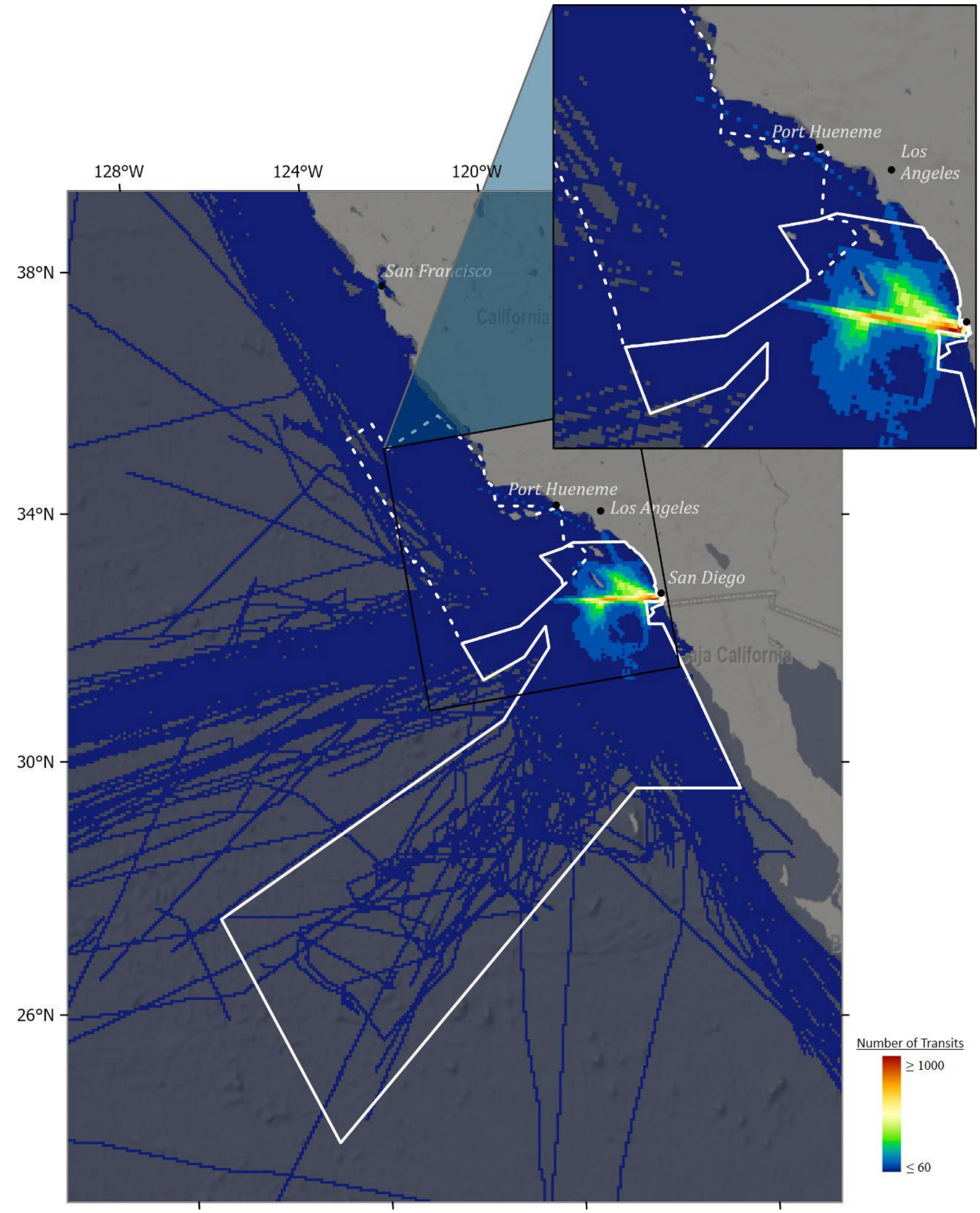


Figure D.2-5: Intensity of military vessel traffic in the California portion of the Study Area from 2014 to 2018. Source: Starcovic and Mintz (2021).

Spectral characteristics of individual ships can be observed at short ranges and in isolated environments. At long ranges, multiple vessels contribute to the overall background noise from ocean traffic in the 10 Hz to 1 kHz band (Figure D.2-1). In shallow water, vessel noise repeatedly interacts with the seafloor and surface and is attenuated by reflection, scattering, and absorption. In deep water, vessel noise propagates downward with fewer interactions with the seafloor and surface and undergoes less attenuation (Erbe et al., 2019). Low-frequency components of vessel noise can propagate long distances in deep water and can travel across ocean basins with minimal energy loss especially within the sound fixing and ranging (SOFAR) channel (Erbe et al., 2019). In areas with sloping bathymetry, vessel noise generated in shallow water can radiate into deeper water due to downward propagation and can couple into the SOFAR channel and propagate long distances (Erbe et al., 2019; Hildebrand, 2009). As a result, vessel noise generated in shallow nearshore waters can still be present in deep offshore waters many kilometers away from the source.

Commercial shipping's contribution to ambient noise in the ocean increased by as much as 12 dB between approximately the 1960s and 2005 and has been attributed to economic growth (Hildebrand, 2009; McDonald et al., 2008). Frisk (2012) confirmed the trend and reported that between 1950 and 2007 ocean noise in the 25 to 50 Hz frequency range has increased 3.3 dB/decade. Assuming a constant baseline level of 52 dB (decibels re 1 $\mu Pa^2/Hz$) during this time results in a cumulative increase of approximately 19 dB. In areas with high levels of shipping traffic, daily average sound levels in the 63 and 125 Hz one-third octave bands were found to be near or higher than 100 dB re 1 μPa (Haver et al., 2021). Daily average sound levels were between approximately 10 to 20 dB higher relative to areas with lower levels of shipping activity (Haver et al., 2021). Temporary reductions in vessel traffic following the events of September 11, 2001 showed an overall decrease of 6 dB (from 50 Hz to 20 kHz), with a notable decrease under 150 Hz (Rolland et al., 2012). Similarly, reduced vessel traffic at the onset of the COVID-19 pandemic resulted in a decrease of 1.5 to 1.7 dB (below 100 Hz) (Breeze et al., 2021; Dahl et al., 2021; Thomson, 2020). Reductions during the COVID-19 pandemic can be attributed to reduced economic activity and shipping (Thomson, 2020); however, noise levels were also subject to local variations such as seasonal environmental conditions and the types of vessels active (Breeze et al., 2021; Dahl et al., 2021).

D.2.2.2 Sonar

Active sonar and other transducers emit non-impulsive sound waves into the water to detect objects, safely navigate, and communicate. The contribution of sonar to the acoustic habitat is highly varied and depends on source characteristics (e.g., frequency, source level, directionality, and duty cycle) and factors that affect sound propagation (e.g., temperature, salinity, pressure, and bathymetry). Temporal and spatial usage are also highly varied and can range from minutes to approximately a month, and from tens to hundreds of kilometers (National Research Council, 2003). Frequency ranges for categorizing sonars are relative, and generalized divisions that are commonly used include: low-frequency (less than 1 kHz), mid-frequency (1-10 kHz), high-frequency (10-100 kHz), and very high-frequency (greater than 100 kHz) (National Research Council, 2003). Given appreciable differences in usage and source characteristics, the contribution of sonar to the acoustic habitat is distinguished between military and commercial sonar systems.

Military sonar systems encompass all three frequency divisions and includes sources with wider beam widths and higher source levels compared with commercial sonar systems. Spatial and temporal usage is well defined both in terms of hours of operation, and the locations where activities occur. Activities are episodic and can last from hours, days to weeks, and over a month (National Research Council, 2003). Examples of military specific applications include low-frequency surveillance sonar, mid-frequency tactical sonar, and high-frequency sonar from weapons.

Compared with military sonar systems, commercial sonar systems use higher frequency signals, have lower source levels, narrower beam patterns that are downward directed, shorter pulse lengths, and are typically operated for minutes to days (National Research Council, 2003). Usage is widespread across locations and sectors including recreation, fishing, shipping, and research. Sources such as depth finders, multi-beam echosounders, and side-scan sonar are also utilized for military applications. Examples of common commercial sonar systems include depth finders and fish finding sonar (15 to 200 kHz) (Širović et al., 2020), both of which focus sound in a downward beam. Depth finders tend to be used in shallow and nearshore waters for navigation whereas fish finding sonar are operated in both shallow and deep waters. Acoustic deterrent and harassment devices and low powered pingers (5 to 160 kHz) (Hildebrand, 2009) are used by fisheries to protect catch from predation. Sea floor mapping for seismic surveys and research utilize multi-beam echosounders (12 to 600 kHz) and side-scan sonar (65 to 500 kHz) (Crocker & Fratantonio, 2016; Ruppel et al., 2022).

D.2.2.3 Explosions

Underwater explosions generate broadband high intensity impulsive sounds that propagate equally in all directions. The spectral and amplitude characteristics of explosions vary with the weight of the charge and the depth of the detonation. Most energy is at lower frequencies from tens to hundreds of Hertz. Explosions are typically localized and propagate tens of kilometers, with the exception of acoustic tomography experiments that measure temperatures and currents over large regions of the ocean and can propagate hundreds to thousands of kilometers (National Research Council, 2003). Military applications of underwater explosives include bombs, mines, missiles, rockets, torpedoes, and projectiles. Spatial and temporal usage under the current action is well defined both in terms of counts of explosives, and the locations where activities occur. Commercial applications of underwater explosives include using explosives as an acoustic sound source for reflection seismology (i.e., rock/sediment penetration and determination) in geophysical exploration (i.e., oil and gas surveys) and for oceanographic research to study underwater acoustic tomography. The use of explosive sound sources for seismic surveys have largely been replaced by air guns due to environmental and handling safety concerns, as well as the lack of control when reproducing signals. Explosives are commonly used for decommissioning marine structures such as offshore oil and gas platforms by severing pilings and conductor pipes at the seafloor (Klima et al., 1988). In addition, small explosive charges known as seal bombs are commonly used by the fishing industry to protect fishing equipment and catch from predation by deterring marine mammals (Krumpel et al., 2021).

D.2.2.4 Industrial Activities

In many areas of the world, oil and gas seismic exploration in the ocean is undertaken using a group of air guns towed behind large research vessels. The air guns convert high-pressure air into very strong shock wave impulses that are designed to return information from the various buried layers of sediment under the seafloor. Most of the impulse energy (analogous to underwater explosions) produced by air guns is heard as low-frequency noise, which can travel long distances, especially in deep water. Most energy is below 200 Hz with additional energy extending to the kilohertz range (Greene & Richardson, 1988; Ruppel et al., 2022). Similar to air guns, other sources that generate an impulse for sub-bottom profiling include: boomers, which use an actuator to displace a near-surface and downward oriented metal plate; sparkers, which discharge a high voltage electric field to vaporize salt water; and bubble guns, which compress air within a plate or pair of plates (Crocker & Fratantonio, 2016; Ruppel et al., 2022). Seismic exploration surveys can encompass areas from tens of kilometers to over one hundred kilometers, and last from days to months (National Research Council, 2003).

The operation of offshore oil and gas extraction platforms produces nearly continuous noise primarily from 20 to 1,000 Hz (Greene & Richardson, 1988) and includes ancillary noise from support vessels and machinery. Oil and gas extraction is typically conducted on offshore platform rigs, drill ships, or artificial islands. Emplacement of permanent structures produces localized noise and lasts for weeks (National Research Council, 2003). Drill ships are generally the loudest with most broadband energy between 10 Hz and 10 kHz (Richardson et al., 1995b). This is because internal ship noise from machinery is effectively transmitted through the hull, and from the use of thrusters for dynamic positioning during drilling operations.

Pile driving is conducted for construction of nearshore structures such as piers, and for offshore structures including wind farm turbines and oil and gas platforms. Installing piles uses an impact hammer which results in an impulsive sound emanating from the length of the pile into the water column as well as from the bottom of the pile through the sediment. Because the impact wave travels through a steel pile at speeds faster than the speed of sound in water, a steep-fronted acoustic shock wave is formed in the water (Reinhall & Dahl, 2011). Piles can also be installed by vibratory pile driving and removed by vibratory extraction, which generates continuous non-impulsive noise with peak pressures lower than impact pile driving. Sound levels can vary depending on the size and power level of the equipment, pile material and diameter, and seafloor sediment type. Installation and removal can encompass areas from less than one kilometer to hundreds of kilometers, and near-continuous activity can last from days to months (National Research Council, 2003).

The construction of offshore wind farms can take weeks to months to complete and produces localized low-frequency noise less than 2 kHz (Amaral, 2020). Most construction noise is produced from pile driving with ancillary noise from laying cable and support vessels. During operation, wind farms produce continuous low-frequency underwater noise primarily below 1 kHz, with tonals between 20 and 330 Hz (Pangerc et al., 2016).

D.3 FISHES

This section describes general effects to fishes from exposure to acoustic and explosive sources, including potential responses from species that may not be present in the Study Area. Despite data gaps in the available literature (as mentioned throughout), the research synthesized here is considered best available science and are used to support the conclusions made in the Action Proponents impact analysis.

D.3.1 HEARING AND VOCALIZATIONS

All fishes have two sensory systems that can detect sound in the water (Popper et al., 2019; Popper & Schilt, 2008; Schulz-Mirbach et al., 2020). The first system discussed herein is the lateral line, which consists of a series of neuromasts (i.e., receptors) along the body that are directly exposed to the environment. When a vibration occurs within the water column that reaches the fish, the receptors along the laeral line move and this movement is transferred through the nervous system to the brain, where it is interpreted. These receptors are sensitive to external particle motion, specifically at frequencies up to 400 Hz (Coombs & Montgomery, 1999; Hastings & Popper, 2005; Higgs & Radford, 2013; Webb et al., 2008), created by sources within a few body lengths of an animal (i.e., in the near field, see Section D.1.2.4, Particle Motion, for additional information).

The second sensory system is the inner ear. The inner ear in fishes functions similarly to the inner ear in other vertebrates. Generally, the inner ears of bony fishes contain three dense otoliths (i.e., small calcareous bodies, although some fishes may have more) that sit atop many delicate mechanoelectrical hair cells within the inner ear. Underwater sound waves pass through the fish’s body due to different structural densities (i.e., soft tissue versus bone) and vibrate the otoliths. As a result, sound waves cause relative motion between the dense otoliths and the surrounding tissues, causing movement of the hair cells back and forth, which is sensed by the nervous system like the stimulation of the receptors along the lateral line. Note, the inner ears are directly sensitive to acoustic particle motion like sensory receptors along the lateral line rather than acoustic pressure. However, some fishes possess morphological adaptations or specializations that can enhance their sensitivity to sound pressure, such as a gas-filled swim bladder (Astrup, 1999; Popper & Fay, 2010). The swim bladder can enhance sound detection by converting acoustic pressure into localized particle motion, which may then be detected by the inner ear (Radford et al., 2012). Fishes with a swim bladder generally have greater auditory sensitivity and can detect higher frequencies than fishes without a swim bladder (Popper & Fay, 2010; Popper et al., 2014){Maurer, 2024, `#23674}. In addition, some fishes contain small horn-like projections that can either partially or fully connect the swim bladder and the inner ear increasing sensitivity and allowing for higher frequency detection (up to a few kilohertz or higher for some species) and better sound pressure detection (e.g., Vetter & Sisneros, 2020). For simplicity and consistency with terminology used in other taxa sections within this EIS/OEIS, and peer-reviewed research, acoustic detection capabilities by either sensory system will generally be described as 'hearing' throughout this discussion.

Propagating sound waves contain pressure and particle motion components but particle motion is most prominent at low frequencies and is most detectible at high-sound pressures or very close to a sound source. Historically, studies have investigated acoustic detection (e.g., hearing research) and its effects on fishes. However, when exposed to a sound, often only sound pressure is measured and not particle motion. Although particle motion may be the more relevant exposure metric, few data are available that actually measure particle motion due to a lack of standard methodology and experience with particle motion detectors (Hawkins et al., 2015; Martin et al., 2016). In these instances, particle motion can be estimated from pressure measurements (Nedelec et al., 2016a). Similarly, although the lateral line likely plays a significant role in a fish's auditory capabilities, this portion of the sensory system is not always included in hearing experiments. Due to the limited research on lateral line sound detection, the majority of research summarized in this section focuses on inner ear sound detection.

Although many researchers have investigated acoustic detection in fishes (Ladich & Fay, 2013; Popper et al., 2014), hearing data (i.e., audiograms) only exist for just over 100 of the estimated 36,000 species of fish worldwide (Fricke et al., 2020). Therefore, fish categories are defined by species that possess a similar continuum of anatomical features, which result in varying degrees of estimated acoustic detection capabilities (Popper & Fay, 2010; Popper & Hastings, 2009b; Schulz-Mirbach et al., 2020; Stanley et al., 2020; Wiernicki et al., 2020){Barbeau, 2024, `#23670}. Specifically, fishes with specialized adaptations connecting the swim bladder to the inner ear have traditionally been categorized as "hearing specialists," while fishes that do not possess specialized structures or swim bladders have been referred to as "hearing generalists" (Popper et al., 2003). Specialists can detect a wide range of frequencies at lower sound levels (i.e., auditory thresholds) compared to generalists that typically detect a much narrower range of frequencies at higher sound levels. Categories and descriptions of the general acoustic detection capabilities for these groups are further defined in Table D.3-1 (modified from Popper et al., 2014). Additional research is still needed to better understand species-specific frequency detection capabilities and continues to help clarify how various anatomical features interact within the auditory system and influence overall sensitivity to sound.

Table D.3-1: Fish Hearing Groups and Categories

Hearing Group	*Fish Category*	*Description*
Hearing Generalists	Fishes without a swim bladder	Acoustic detection capabilities are limited to particle motion detection at frequencies well below 2 kHz (e.g., sharks, rays, and halibut).
	Fishes with a swim bladder not involved in hearing	Fishes lack notable anatomical specializations and primarily detect particle motion at frequencies below 2 kHz (e.g., salmonids, sturgeon, and groupers).
Hearing Specialists	Fishes with a swim bladder involved in hearing	Fishes can detect frequencies below 2 kHz, possess anatomical specializations to enhance hearing, and are capable of sound pressure detection up to a few kHz (e.g., herring, sardines, anchovy).
	Fishes with a swim bladder and with high-frequency hearing	Fishes possess anatomical specializations and are capable of sound pressure detection at frequencies up to 10 kHz, or over 100 kHz in some species (shad and menhaden).

Data suggest that most species of marine fish are hearing generalists and either lack a swim bladder (e.g., sharks and flatfishes) or have a swim bladder not involved in acoustic detection (e.g., sturgeon and codfishes) and can only detect sounds below 2 kHz. Fewer marine fishes (Clupeiformes) are hearing specialists (i.e., those with a swim bladder involved in hearing). These species can detect sounds up to about 4 kHz (Colleye et al., 2016; Mann et al., 2001; Mann et al., 1997; Mickle & Higgs, 2021). One subfamily of clupeids (i.e., Alosinae or shads) can detect high- and very high-frequency sounds (i.e., frequencies from 10 to 100 kHz, and frequencies above 100 kHz, respectively), although sensitivity at these higher frequencies are elevated and the range of best sensitivity is still in the low-frequency range (below 1 kHz) like other fishes. It was theorized that this subfamily may have evolved the ability to hear relatively high sound levels at these higher frequencies to detect echolocation signals of nearby foraging dolphins (Mann et al., 1998; Mann et al., 1997). For fishes that have not had their hearing tested, such as deep sea fishes, the suspected hearing capabilities are based on the structure of the ear, the relationship between the ear and the swim bladder, and other potential adaptations such as the presence of highly developed areas of the brain related to inner ear and lateral line functions (Buran et al., 2005; Deng et al., 2011, 2013). It is believed that most fishes have their best sensitivity from 100 to 400 Hz (Popper et al., 2003). Seasonal variations in auditory sensitivity have been reported in some fishes, such as the plainfish midshipman, which have likely evolved to aid in reproductive behaviors (i.e., detection of suitable mates) (e.g., Rogers et al., 2022; Sisneros & Bass, 2003).

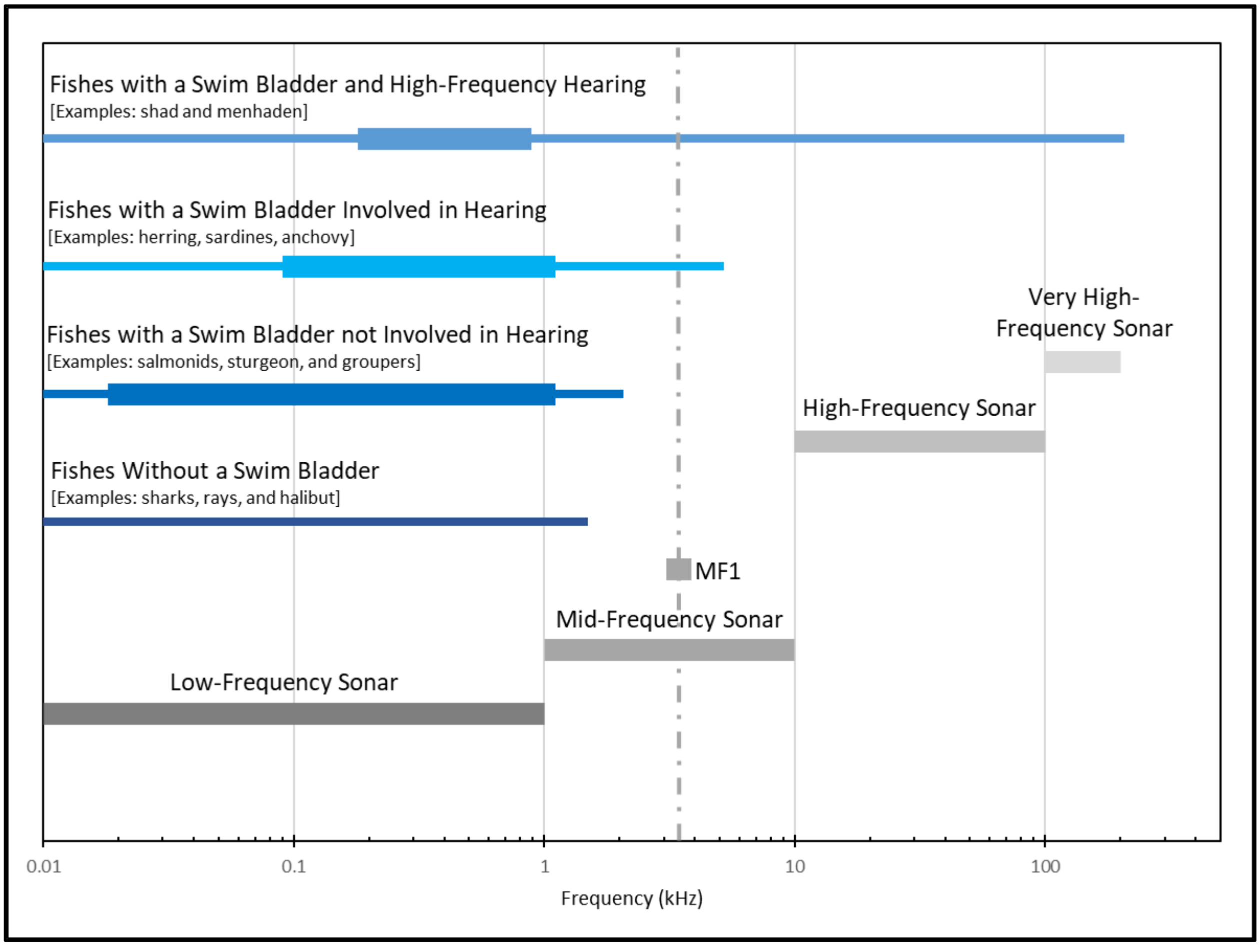
Bony fishes can produce sounds in several ways and use them for a variety of behavioral functions (Kasumyan, 2009; Ladich, 2008, 2014). The most common mechanism for sound production is when the swim bladder and other structures (often muscles that are associated with the swim bladder wall) vibrate and radiate sound into the water (Zelick et al., 1999). Additional mechanisms include, but are not limited to, muscular vibrations, rubbing, or plucking of pectoral fins (including the girdle, spines, or tendons) and grinding or rubbing of teeth, jaw apparatuses, or even bones in the skull (Kasumyan, 2008; Ladich, 2008). Over 30 families of fishes are known to produce acoustic signals in aggressive interactions, and over 20 families of fishes vocalize during courtship or mating (Ladich, 2008). Sounds generated by fishes as a means of communication are generally narrow band and below 500 Hz, though some acoustic signals have been recorded at frequencies up to 5,000 Hz (Kasumyan, 2008; Ladich, 2000; McCauley & Cato, 2000; Slabbekoorn et al., 2010). Acoustic signals may vary in source level depending on factors such as the sound production mechanism, species, size of fish, behaviors associated with the signal, and even environmental factors (Kasumyan, 2009). Likely in connection to seasonal variations in auditory sensitivity, call rates can also vary daily or seasonally (e.g.`, Hom, 2024, `#21535}. Some of the loudest recorded vocalizations are from fish choruses with approximate source levels up to 170 dB re 1 µPa (Erisman & Rowell, 2017; McCauley & Cato, 2000; McIver et al., 2014; Sisneros & Bass, 2003; Sprague & Luczkovich, 2004).

Combined research methods that utilize visual surveys (such as baited underwater video and monitoring by divers) and passive acoustic monitoring continue to reveal new sounds produced by fishes both in the marine and freshwater environments. Such experiments allow for specific behaviors to be paired with recorded signals, the identification of sex-specific vocalizations, and may be useful in determining more approximate estimates of the total number of soniferous (e.g., sound producing) fishes in a given habitat (Bussmann, 2020; Parmentier et al., 2021; Radford et al., 2018; Rountree et al., 2018; Rowell et al., 2020; Rowell et al., 2018).

D.3.1.1 Detection of Navy Sonars

As described above, fishes are not equally sensitive to noise at all frequencies. Figure D.3-1 provides a general summary of hearing threshold data from available literature (Casper & Mann, 2006; Deng et al., 2013; Kéver et al., 2014; Mann et al., 2001; Ramcharitar et al., 2006) to demonstrate the potential overlap of frequency detection for each fish category with Navy sonars. Fishes from all categories can detect broadband sound sources such as explosives or vessel noise. But, as displayed, not all fishes would detect some frequency-limited sources, such as high-frequency sonar.

These estimated ranges of frequency detection may be overly conservative in that they may extend beyond what some species within a given fish hearing category may detect. For example, although many sharks are most sensitive to lower frequencies, well below 1 kHz, the bull shark (*Carcharhinus leucas*) can detect frequencies up to 1.5 kHz (Kritzler & Wood, 1961; Myrberg, 2001), representing the uppermost known limit of frequency detection for this hearing category. These upper bounds of each fish category's frequency range are outside of the range of best sensitivity for most fishes within that category. As a result, fishes within each group would only be able to detect those upper frequencies at close distances to the source, and from sources with relatively high source levels.



Notes: Thin blue lines represent the estimated minimum and maximum range of frequency detection for each fish category. All groups are assumed to detect frequencies down to 10 Hz regardless of available data. Thicker portions of each blue line represent the estimated minimum and maximum range of best sensitivity for that group. Not all fishes within a given category would be able to detect all the displayed frequencies. For example, flatfish such as halibut can only detect frequencies up to 270 Hz, although other fishes in the same hearing group can detect much higher frequencies (e.g., bull sharks can detect up to 1,500 Hz, the upper limit of the hearing group). Each sonar source class that occurs in the Study Area is represented graphically by the horizontal grey bars. Not all sources within each class would operate at all the displayed frequencies and may not overlap all fish hearing groups as demonstrated by the dotted grey line. kHz = kilohertz, MF1 = center frequency of 3.5 kHz.

Sources: Casper and Mann (2006); Chapman and Hawkins (1973); Chapman and Sand (1974); Hawkins and Johnstone (1978); Mann et al. (2005); Popper (2008); Popper et al. (2007); Tavolga and Wodinsky (1963)

Figure D.3-1: Fish Categories and Navy Sonars

D.3.2 Hearing Loss and Auditory Injury

Impairment of auditory detection (more commonly referred to as hearing loss) or auditory injury will have an immediate effect on an animal's ability to detect certain frequencies. For this reason, hearing loss and auditory injury are often discussed together. However, the sensory hair cells of the inner ear and lateral line in fishes are regularly replaced over time when they are damaged, unlike in mammals where sensory hair cells loss is permanent (Lombarte et al., 1993; Popper et al., 2014; Smith et al., 2006). Consequently, PTS has not been known to occur in fishes, and any hearing loss in a fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2014; Popper et al., 2005; Smith et al., 2006).

Data for some terrestrial mammals have shown signs of auditory injury in the form of nerve damage after severe threshold shifts (e.g., Kujawa & Liberman, 2009; Lin et al., 2011). In fishes, studies have observed cellular changes in hearing structures after long-term sound exposures (Sapozhnikova et al., 2020), as well as hair cell damage and tearing of the epithelial lining after exposure to underwater detonations at close range (Smith et al., 2022){Bowman, 2024, `#23443}. However, it is not known if physical damage such as those described here would be recoverable in fishes (like hair cell regeneration noted in other studies), or if there would be hearing impairment. One of the few studies to look at both auditory sensitivity (measured by threshold shifts) and potential physical damage to the inner ear include research using zebrafish (*Danio rerio,* a freshwater hearing specialist) (Breitzler et al., 2020). The experiment demonstrated a lack of damage to sensory receptors when temporary threshold shift (TTS) occurred though this has not been investigated in marine species (for additional details on the results of this experiment, see D.3.2.2, Threshold Shift due to Vessel Noise).

D.3.2.1 Threshold Shift due to Sonar and Other Transducers

Several studies have examined the effects of the sound exposures from low-frequency sonar on fish hearing (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Hearing was measured both immediately post exposure and for up to several days thereafter (Halvorsen et al., 2013; Kane et al., 2010; Popper et al., 2007). Maximum SELs were 218 or 220 dB re 1 μPa^2s at frequencies ranging from 170 to 320 Hz (Kane et al., 2010; Popper et al., 2007) and 215 dB re 1 μPa^2s in a follow-on study (Halvorsen et al., 2013). Two hearing generalists, the largemouth bass (*Micropterus salmoides*) and yellow perch (*Perca flavescens*), showed no loss in detection sensitivity from sound exposure immediately after the test or 24 hours later. Channel catfish (*Ictalurus punctatus*), a hearing specialist, and some specimens of rainbow trout (*Oncorhynchus mykiss)*, a hearing generalist, showed a threshold shift (up to 10–20 dB) immediately after exposure to the low-frequency sonar when compared to baseline and control animals. Small thresholds shifts were detected for up to 24 hours after the exposure in some channel catfish. Although some rainbow trout in one test group showed signs of TTS, rainbow trout in another group showed no TTS. Catfish hearing returned to normal within about 24 hours after exposure to low-frequency sonar. Examination of the inner ears of the fish during necropsy revealed no differences from the control groups in ciliary bundles or other features indicative of hearing loss.

The same investigators examined the potential effects of mid-frequency active sonar on rainbow trout and channel catfish hearing (Halvorsen et al., 2012c; Kane et al., 2010). The maximum received cumulative SEL was 220 dB re 1 μPa^2s. No significant TTS was observed in rainbow trout. Of the catfish tested, only the group tested in October experienced TTS (6.35 dB), which recovered within 24 hours, but fish tested in December showed no TTS (Halvorsen et al., 2012c; Kane et al., 2010).

Some studies have suggested that there may be some loss of sensory hair cells due to high intensity sources, indicating a possible loss in hearing sensitivity; however, none of those studies investigated the subjects' actual hearing range after exposure to these sources. Enger (1981) found loss of ciliary bundles of the sensory cells in the inner ears of Atlantic cod (*Gadus morhua*), hearing specialists, following one to five hours of exposure to pure tone sounds between 50 and 400 Hz with a SPL of 180 dB re 1 µPa. Hastings (1995) found auditory hair-cell damage in goldfish (*Carassius auratus*), a freshwater hearing specialist. Goldfish were exposed to 250 Hz and 500 Hz continuous tones with maximum peak SPLs of 204 dB re 1 µPa and 197 dB re 1 µPa, respectively, for about two hours. Similarly, Hastings et al. (1996) demonstrated damage to some sensory hair cells in oscars (*Astronotus ocellatus*) observed one to four days following a one-hour exposure to a pure tone at 300 Hz with an SPL of 180 dB re 1 µPa. Both studies found a relatively small percentage of total hair cell loss from hearing organs despite long-duration exposures. Effects from long-duration noise exposure studies are generally informative; however, they are not necessarily representative of effects from intermittent, short-duration exposures produced during Navy activities involving sonar and other transducers.

As noted in the *American National Standards Institute (ANSI) Sound Exposure Guideline* technical report (Popper et al., 2014), some hearing specialists may be more susceptible to TTS from high-intensity, non-impulsive sound sources, such as sonar and other transducers, depending on the duration and frequency content of the exposure. Fishes that are hearing specialists may exhibit TTS from exposure to low- and mid-frequency sonar, specifically at cumulative SELs above 215 dB re 1 µPa^{2}s. However, hearing generalists would be unlikely to detect mid- or other high-frequency sonars and would likely require a much higher SEL to exhibit the same effect from exposure to low-frequency active sonar.

D.3.2.2 Threshold Shift due to Vessel Noise

The following section summarizes data on the effects of vessel noise on fish hearing. For example, Rogers et al. (2020) examined the effects of vessel noise playbacks on the oyster toadfish, a hearing generalist. Toadfish were exposed to one of three noise conditions and hearing thresholds were measured before and multiple days (up to 9) after exposure. Two groups of fish were exposed to recorded boat noise (30 to 12,000 Hz frequency range) for either 1 or 12 hours continuously, and a third group was exposed to 12 hours of biological noise (male toadfish vocalizations, called boatwhistles, with a fundamental frequency of 180 Hz). SPLs for all noise conditions were maintained at approximately 150 dB re 1 µPa and fell within the oyster toadfish frequency sensitivity of 80-550 Hz. Exposures to biological signals, even for a duration of 12 hours, did not result in any hearing impairment. However, significant TTS of up to 8 and 20 dB was observed after exposures of 1 and 12 hours of vessel noise, respectively. More often, TTS has been studied in captive fishes exposed to elevated background noise and other non-impulsive, broadband[1] sources such as white noise (e.g., Breitzler et al., 2020; Scholik & Yan, 2002b; Smith et al., 2004b; Wysocki & Ladich, 2005).

Caged studies on hearing specialists show some hearing loss after several days or weeks of exposure to increased background sounds, although the hearing loss seems to recover (e.g., Breitzler et al., 2020; Scholik & Yan, 2002a; Smith et al., 2006; Smith et al., 2004a). Smith et al. (2006) and Smith et al. (2004a) exposed goldfish to noise with a SPL of 170 dB re 1 µPa and found a clear relationship between the amount of hearing loss and the duration of exposure until maximum hearing loss occurred 24 hours after exposure. A 10-minute exposure resulted in 5 dB of TTS, whereas a three-week exposure resulted in a 28 dB TTS that took over two weeks to return to pre-exposure levels (Smith et al., 2004a). Recovery times were not measured by investigators for shorter exposure durations.

Scholik and Yan (2001) demonstrated TTS in a hearing specialist, the fathead minnow (*Pimephales promelas*), after a 24-hour continuous exposure to white noise (0.3–2.0 kHz) at 142 dB re 1 µPa that took up to 14 days post-exposure to recover. This is the longest recorded time for a threshold shift to recover in a fish. The same authors also found that the bluegill sunfish (*Lepomis macrochirus*), a generalist, did not show significant elevations in auditory thresholds when exposed to the same stimulus (Scholik & Yan, 2002b). Likewise, {Maurer, 2023, `##23674@@author-year} exposed common roach (*Rutilus rutilus*), a pelagic hearing specialist, and sand gobies (*Pomatoschistus minutus*), a benthic hearing generalist, to simulated continuous broadband (100 – 10,000 Hz) vessel noise for 256 seconds

[1] A sound or signal that contains energy across multiple frequencies.

with peak SPLs between 154-164 dB re 1 µPa and SEL_{cum} levels 180-190 dB re 1µPa^{2}s. The common roach had significant TTS when exposed to a subset of the noise exposures while the sand gobies did not. This evidence supports that hearing specialists may be more sensitive to hearing loss when exposed to noise than fishes that are considered hearing generalists.

Breitzler et al. (2020) exposed zebrafish (a freshwater hearing specialist) to 24 hours of white noise at various frequencies and sound levels. TTS was observed at frequencies that were within the fish's best hearing sensitivity. Recovery took up to 14 days for fish exposed to the highest SPL (150 dB re 1 µPa). The highest threshold shifts recorded (up to 33 dB) also resulted in significant hair cell loss, whereas lower exposure levels did not. Like the other effects measured in this study, hair cell loss attributed to the highest exposure level returned to baseline levels within 7 days post-exposure. This demonstrates the ability for fish to regenerate hair cells and for hearing thresholds to recover to baseline levels (lacking evidence of PTS).

Wong et al. (2022) exposed zebrafish to 24 hours of white noise with four different temporal patterns (continuous fast and slow, regular and irregular intermittent). Impacts from white noise at SPLs of approximately 150 dB re 1 µPa included noise induced hearing loss, physical damage, and behavioral responses (discussed further in Section D.3.4.1). Auditory evoked potentials were used to measure significant threshold shifts (an average of approximately 13 dB across all tested frequencies) for all four temporal patterns. Although significant hair cell loss was not found, other indications of physical damage were reported including decreased Ribeye b protein and splaying of inner ear epithelial. Wong et al. (2022) proposed that the total acoustic energy of a given signal may play a larger role in observed effects than the temporal patterns of the signal.

Although TTS has been reported in larval zebrafish as early as five days post fertilization exposed to white noise at frequencies below 1.5 kHz with a SPL of 150 dB re 1 µPa, the actual duration of the exposure was not reported (Lara et al., 2022). Unlike the previous study, an analysis of the change in hair cell numbers, epithelia area, and general hair cell density showed varying responses to the sound source. Overall, there were no significant reductions in hair cell density between noise and control groups.

A direct comparison of results from these studies to fishes exposed to continuous sound sources in natural settings should be treated with caution due to differences between laboratory and open ocean or coastal environments. For example, fishes that are exposed to noise produced by a vessel passing by in their natural environment, even in areas with high levels of vessel movement, would only be exposed for short durations (e.g., seconds or minutes) and therefore relatively low SELs by transiting vessels. Fishes used in laboratory experiments are often held in a tank during exposures without any possibility to avoid the noise source and test species are often freshwater hearing specialists (e.g., goldfish or zebrafish) due to ease of availability from commercial sources. Furthermore, small aquariums present issues when transmitting acoustic signals as there may be excessive particle motion not accurately measured and accounted for during the experiment (e.g., Okumura et al., 2002). As evidence suggests that fish can recover from hearing loss (both threshold sensitivity and actual physical damage) even after long duration exposures in a confined space, it also indicates similar results to lower level and shorter duration exposures. Therefore, overall effects would not likely rise to the level of impact demonstrated in the summarized laboratory studies.

As noted in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), hearing specialists may be more susceptible to TTS from long duration continuous noise, such as broadband white noise, depending on the duration of the exposure (thresholds are proposed based on continuous exposure of 12 hours). However, it is less likely that TTS would occur in fishes that are hearing generalists.

D.3.2.3 Threshold Shift due to Impulsive Sound Sources

Popper et al. (2005) examined the effects of a seismic air gun array on a hearing specialist, the lake chub (*Couesius plumbeus*); and two hearing generalists, the northern pike (*Esox lucius*) and the broad whitefish (*Coregonus nasus*), a salmonid. In this study, fish were placed in pens in a shallow river (with water depths of 1.9 m) and exposed to either five or 20 shots from a nearby small air gun array (eight air guns total). Effects were noted at a cumulative SEL of 186 dB re 1 μPa^2s, based on an exposure of five shots with a mean single strike SEL of 177 dB re 1 μPa^2s (Popper et al., 2014). Like most air gun signals, each shot lasted a few milliseconds with the 5 shot exposure likely lasting a few minutes based on the 15 minutes it took to expose fish to 20 shots (pulse length and pulse interval was not reported). TTS was reported in the lake chub and northern pike, but not in the broad whitefish. Approximately 20–25 dB of TTS was reported at some, but not all tested frequencies for both species, and full recovery from threshold shifts took place within 18 hours after sound exposure. Examination of the sensory surfaces of the ears after allotted recovery times (one hour for five shot exposures, and up to 18 hours for 20 shot exposures) showed no damage to sensory hair cells in any of the fish from these exposures (Song et al., 2008).

A small percent (2-15% depending on the region and test group) of sensory hair cells in the inner ear was observed in caged fishes exposed to multiple passes of a towed air gun array at distances from five to several hundred meters (McCauley et al., 2003; McCauley & Kent, 2012). Pink snapper (*Chrysophrys auratus*), a hearing generalist, were exposed to multiple air gun shots for up to one and one-half hours (McCauley et al., 2003) where the maximum received SELs exceeded 180 dB re 1 μPa^2s. Though there were no long-term controls to compare to, the loss of sensory hair cells continued to increase for up to at least 58 days post exposure to 2.7 percent of the total cells. Gold band snapper (*Pristipomoides multidens*) and sea perch (*Lutjanus kasmira*), both hearing specialists, were also exposed to a towed air gun array simulating a passing seismic vessel (McCauley & Kent, 2012). Although received levels for these exposures have not been published, hair cell damage increased as the range of the exposure (i.e., distance to the source) decreased. Again, the amount of damage was considered small in each case (McCauley & Kent, 2012). It is not known if this hair cell loss would result in TTS since fish have tens or even hundreds of thousands of sensory hair cells in the inner ear and only a small portion were affected by the sound (Lombarte & Popper, 1994; Popper & Hoxter, 1984). A reason McCauley and Kent (2012) found damage to sensory hair cells, while Popper et al. (2005) did not, may be in their distinct methodologies. Their studies had many differences, including species and the precise sound source characteristics.

Hastings et al. (2008) exposed a hearing specialist, the pinecone soldierfish (*Myripristis murdjan*), and three hearing generalists, the blue green damselfish (*Chromis viridis*), the saber squirrelfish (*Sargocentron spiniferum*), and the bluestripe seaperch (*Lutjanus kasmira*) to a nearby active seismic survey. Fish were located at one of three test sites that varied in distance from the actual survey (approximately 45 m to several kilometers). Fish in cages were exposed to multiple air gun shots with a cumulative SEL of 190 dB re 1 μPa^2s. The authors found no TTS in any fish examined up to 12 hours after the exposures.

In an investigation of another impulsive source, Casper et al. (2013b) found that some fishes may actually be more susceptible to barotrauma (e.g., swim bladder ruptures, herniations, and hematomas) than effects to the auditory system when exposed to simulated impact pile driving. Hybrid striped bass (white bass *Morone chrysops* x striped bass *M. saxatilis*) and Mozambique tilapia (*Oreochromis mossambicus*), both hearing generalists, were exposed to SELs between 213 and 216 dB re 1 µPa^{2}s. The subjects exhibited barotrauma, and although researchers began to observe signs of inner ear hair cell loss, these effects were small compared to the other non-auditory injuries that occurred. Smith et al. (2022) observed physical damage in the inner ear of a hearing generalist, Pacific mackerel (*Scomber japonicus*), exposed to underwater explosions starting at received peak to peak SPLs of 220 dB re 1 µPa. Though there are no direct measurements of TTS in fishes exposed to explosive sources, it is assumed that fish would demonstrate similar effects on auditory detection as those exposed to other impulsive sources such as those described above. These received sound levels likely represent thresholds at which hearing effects may occur.

PTS has not been known to occur in fishes tested to date. Any hearing loss in fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2014; Popper et al., 2005; Smith et al., 2006). The lowest SEL at which TTS has been observed in fishes with hearing specializations exposed to air gun signals is 186 dB re 1 µPa^{2}s. As reviewed in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), hearing generalists would be less susceptible to TTS than specialists, even at higher levels and longer durations. Fishes that are hearing specialists may be susceptible to TTS within very close ranges to an explosive.

D.3.3 MASKING

Masking is likely to occur in most fishes due to varying levels of ambient or natural noise in the environment, such as wave action, precipitation, or other animal vocalizations (Popper et al., 2014). Ambient noise during higher sea states in the ocean has resulted in masking in several fish species (Chapman & Hawkins, 1973; Ramcharitar & Popper, 2004). Although the overall intensity or loudness of ambient or human-generated noise may result in masking effects in fishes, masking is most problematic when human-generated signals or ambient noise levels overlap the frequencies of biologically important signals (Buerkle, 1968, 1969; Popper et al., 2014; Tavolga, 1974).

Auditory sensitivity can be hindered by masking noise. Wysocki and Ladich (2005) investigated the influence of continuous white noise on the auditory thresholds of two hearing specialists, the goldfish and the lined Raphael catfish (*Platydoras costatus*) as well as a hearing generalist, the pumpkinseed sunfish (*Lepomis gibbosus*). Experiments were conducted in aquariums. Continuous white noise with an SPL of approximately 130 dB re 1 µPa at 1 m resulted in 23–44 dB of masking within the goldfish and catfish region of best sensitivity between 500 and 1,000 Hz. The sunfish experienced only 11 dB of masking during the same noise treatment. In a similar study, meagre (*Argyrosomus regius*) exposed to boat noise at relative SPLs of 130 dB re 1 µPa showed a masking effect of up to 20 dB during presentation of the noise stimulus (Vieira et al., 2021). As seen in previous studies, fish calls were masked by up to 20 dB. Masked auditory thresholds were also measured in the croaking gourami (*Trichopsis vittata*, Osphronemidae) during playbacks of white noise at a relative SPL of 110 dB re 1 µPa (Maiditsch & Ladich, 2022). The experiment revealed a significant increase in auditory thresholds during noise presentations. Specifically, the largest effect was noted at frequencies that overlap with female pre-spawning purring vocalizations.

Masking could lead to potential fitness costs depending on the severity of the reaction and the animal's ability to adapt or compensate during an exposure (e.g., de Jong et al., 2020; Krahforst et al., 2016; Radford et al., 2014; Slabbekoorn et al., 2010). For example, masking could result in changes in predator-prey relationships, potentially inhibiting a fish's ability to detect predators and therefore increase its risk of predation, or limiting a fish's ability to classify and locate prey items, reducing foraging success (e.g., Astrup, 1999; Mann et al., 1998; McCormick et al., 2018; Simpson et al., 2015; Simpson et al., 2016; Voellmy et al., 2014). Alternatively, if the masking noise overlaps the hearing range of fish predators (e.g., marine mammals) or their prey, this could be beneficial if the masking signal prevents predators from finding them or increases their chance of capturing prey items.

Masking may also limit the distance over which fish can communicate or detect important signals, including conspecific vocalizations such as those made during reproductive phases or sounds emitted from a reef for navigating larvae (Alves et al., 2016; Codarin et al., 2009; de Jong et al., 2020; Higgs, 2005; Krahforst et al., 2016; Neenan et al., 2016; Ramcharitar et al., 2006; Ramcharitar et al., 2001; Stanley et al., 2017; Vieira et al., 2021). If the masking signal is brief (a few seconds or less), biologically important signals may still be detected, resulting in little effect to the individual. If the signal is longer in duration (minutes or hours) or overlaps with important frequencies for a particular species, more severe consequences may occur such as the inability to attract a mate and reproduce. These impacts could be avoided via anti-masking responses, such as alterations in the time of day fish vocalize to avoid noisy periods, or changes call type or the frequency content of a call to avoid overlap with anthropogenic sound sources {e.g.`, Hom, 2024, `#21535}{Ogurek, 2024, `#23676}. The Lombard effect has been reported in fishes (both in a laboratory setting and in situ) in an increasing number of experiments (e.g., Holt & Johnston, 2014; Luczkovich et al., 2016b; Somogyi & Rountree, 2023). The Lombard effect is defined as a potentially compensatory behavior where an animal increases the source level of its vocalizations in response to elevated noise levels. The Lombard effect is currently understood to be a reflex that may be unnoticeable to the animal, or it could lead to increased energy expenditure during communication as is possible with other anti-masking responses described above.

Passive acoustic monitoring was conducted during several phases of an offshore windfarm installation project (Siddagangaiah et al., 2021). Installation and active use of the windfarm resulted in increased background noise levels as well as changes in fish chorusing patterns compared to baseline conditions in the Study Area. For example, type 1 choruses occurred for longer durations and at a lower intensity compared to pre-construction monitoring. Type 2 choruses showed an increase in intensity but no change in overall call duration during the same portion of the project installation. After construction was complete, residual effects on call duration and intensity were evident for Type 1 chorusing (increased call duration and intensity) though Type 2 chorusing did not seem affected and returned to baseline levels. Changes in fish vocal behavior may be affected by masking (the Lombard effect) or other factors such as disrupted group cohesion during periods of noise presentation. Although the construction noise included impact pile driving, it is difficult to distinguish whether these impacts were a result of the impulsive signals alone, or if noise from other parts of the activity (vessel movements, dredging, windmill operations) contributed changes in fish chorusing behavior. Additional research has shown that some, but not all species, respond to sound exposures with the Lombard effect (e.g., Brown et al., 2021; Maiditsch & Ladich, 2022).

The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) highlights the lack of data for masking by sonar but suggests that the narrow bandwidth and intermittent nature of most sonar signals would result in only a limited probability of any masking effects. In addition, most sonars (mid-, high-, and very high-frequency) are above the hearing range of most marine fish species (see Figure D.3-1), eliminating the possibility of masking for these species. In most cases, the probability of masking would further decrease with increasing distance from the sound source.

In addition, few data are available for masking by impulsive signals (e.g., impact pile driving and air guns) (Popper et al., 2014; Siddagangaiah et al., 2021). Impulsive sounds are typically brief, lasting only fractions of a second, where masking could occur only during that brief duration of sound. Biological sounds can typically be detected between pulses within close distances to the source unless those biological sounds are like the masking noise, such as impulsive or drumming vocalizations made by some fishes (e.g., cod or haddock). Masking could also indirectly occur because of repetitive impulsive signals where the repetitive sounds and reverberations over distance may create a more continuous noise exposure. Currently there are no direct observations of masking in fishes due to explosives. The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) highlights a lack of data that exist for masking by explosives but suggests that the intermittent nature of explosions would result in very limited probability of any masking effects, and if masking were to occur it would only occur during the duration of the sound. Potential masking from explosives would be similar to masking studied for other impulsive sounds such as air guns.

Although there is evidence of masking because of exposure to vessel noise, the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) does not present numeric thresholds for this effect. Instead, relative risk factors are considered, and the standards committee assumed the probability of masking occurring is higher at near to moderate distances from the source (up to hundreds of meters) but decreases with increasing distance (Popper et al., 2014).

D.3.4 Behavioral Reactions

Behavioral reactions of fishes have been observed across many types of sound sources. Most research has been performed using air guns (including large-scale seismic surveys), sonar, and vessel noise. Fewer observations have been made on behavioral reactions to impact pile driving noise and there are no data available on reactions to explosives, although fish are likely to show similar behavioral reactions to any impulsive noise.

Fish studies have identified the following behavioral reactions to sound: alteration of natural behaviors (e.g., startle or alarm), and avoidance (LGL Ltd Environmental Research Associates et al., 2008; McCauley et al., 2000b; Pearson et al., 1992). In the context of this Supplemental EIS/OEIS, and to remain consistent with behavioral response literature, the terms “startle,” “alarm,” “response,” and “reaction” will be used synonymously. In addition, observed behavioral reactions to sound can include disruption to or alteration of swimming, schooling, anti-predator behaviors, feeding, breeding, and migrating. Sudden changes in sound level can cause fish changes in depth and swimming direction. However, some fish either do not respond, or learn to tolerate or habituate to the noise exposure (e.g., Bruintjes et al., 2016; Currie et al., 2020; Hubert et al., 2020b; Nedelec et al., 2016b; Radford et al., 2016){Maurer, 2023, `##23674}.

Research on behavioral reactions can be difficult to understand and interpret. For example, behavioral responses often vary depending on the type of exposure and sound source. Changes in sound intensity may be more important to a fish’s behavior than the maximum sound level. Some studies show that sounds that fluctuate in sound pressure level or have intermittent pulse rates tend to elicit stronger responses from fish than even stronger sounds with a continuous level (Currie et al., 2020; Neo et al., 2014; Schwarz & Greer, 1984). It has also been suggested that unpredictable sounds that last for long durations may have the largest impact on behavioral responses (de Jong et al., 2020). Interpreting behavioral responses can also be difficult due to species-specific behavioral tendencies, motivational state (e.g., feeding or mating), an individual’s previous experience, how resilient a species is to changes in their environment, and whether the fish are able to avoid the sound source (e.g., caged versus free-swimming subjects). Results from caged studies may not provide a representative understanding of how free-swimming fishes may react to the same or similar sound exposures (Hawkins et al., 2015), especially when the experimental population consists of those species bred and raised in captivity (e.g., generations of captive zebrafish used in biological studies).

D.3.4.1 Behavioral Reactions to Sonar and Other Transducers

Behavioral reactions to sonar have been studied both in caged and free-swimming fish, although results can often-times be difficult to interpret depending on the species tested and the study environment. Jorgensen et al. (2005) showed that caged cod and spotted wolffish (*Anarhichas minor*) lacked any response to simulated sonar between 1 and 8 kHz. However, within the same study, reactions were seen in juvenile herring. It is likely that the sonar signals were inaudible to the cod and wolf fish (species that lack notable hearing specializations) but audible to herring (a hearing specialist).

Several experiments studied the reactions of both wild and captive Atlantic herring (*Clupea harengus*) to the Royal Netherlands Navy's experimental mid-frequency active sonar ranging from 1 to 7 kHz with maximum cumulative SELs of 184 dB re 1 $\mu Pa^2 s$ (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2015a; Sivle et al., 2012a). No avoidance or escape reactions were observed when herring were exposed to sonar sources and the authors concluded that the use of naval sonar poses little risk to populations of herring. Instead, significant reactions were noted at lower received sound levels of different non-sonar sound types. For example, dive responses (i.e., escape reactions) were observed when herring were exposed to killer whale feeding sounds at received SPLs of approximately 150 dB re 1 µPa (Sivle et al., 2012a). Startle responses were seen when the cages for captive herring were hit with a wooden stick and with the ignition of an outboard boat engine at a distance of one meter from the test pen (Doksaeter et al., 2012). It is possible that the herring were not disturbed by the sonar because they were more motivated to continue other behaviors such as feeding, or did not associate the sound as a threatening stimulus as they likely did for the killer whale and outboard motorboat signals.

Short et al. (2020) studied the effect of a broadband, pulsed, acoustically random noise exposure (60–2,000 Hz) on the swimming behavior of a captive freshwater shoaling species (Eurasian minnows, *Phoxinus phoxinus,* hearing specialists). In response to the noise exposure, group responses were more consistent in their escape behavior (e.g., startled, consistent speed, less erratic path, stronger group cohesion, more synchronized orientation) compared to fish tested individually. Although the pulsed tones were broadband, unlike most sonar sources that have a limited center frequency, the study provides insight into the differences in group versus individual reactions particularly for shoaling species.

There is evidence that elasmobranchs (cartilaginous fish including sharks and rays) also respond to human-generated sounds. A number of researchers conducted experiments in which they played back sounds (e.g., pulsed tones below 1 kHz) and attracted a number of different shark species to the sound source (e.g., Casper et al., 2012a; Myrberg et al., 1976; Myrberg et al., 1969; Myrberg et al., 1972; Nelson & Johnson, 1972). The results of these studies showed that sharks, hearing generalists, were attracted to irregularly pulsed low-frequency sounds (below several hundred Hz), in the same frequency range of sounds that might be produced by struggling prey. However, abrupt and irregularly pulsed human-generated noise (0.02–10 kHz, with most energy below 1 kHz) resulted in withdrawal responses of certain shark species (Chapuis et al., 2019). Sharks are not known to be attracted to continuous signals or higher frequencies that they presumably cannot hear (Casper & Mann, 2006; Casper & Mann, 2009).

Only a few species of marine fishes can detect sonars above about 2 kHz, meaning that most fishes would not detect most mid-, high-, or very high-frequency Navy sonars. The few marine species that can detect above 2 kHz and have some hearing specializations may be able to better detect the sound and would therefore be more likely to react. However, researchers have found little reaction by adult fish in the wild to sonars within the animals' auditory detection range (Doksaeter et al., 2009; Doksaeter et al., 2012; Sivle et al., 2012a). The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) suggests that fish able to hear sonars would have a low probability of reacting to the source within near or intermediate distances (within tens to hundreds of meters) and a decreasing probability of reacting at increasing distances.

D.3.4.2 Behavioral Reactions to Vessel Noise

Vessel traffic contributes to the amount of noise in the ocean and has the potential to affect fishes. Several studies have reported and reviewed avoidance responses by fishes (e.g., herring and cod) to vessels or playbacks of vessel noise (De Robertis & Handegard, 2013; Engås et al., 1995; Handegard et al., 2003; Waddell & Sirovic, 2023). For example, Misund (1997) found fish showed avoidance reactions at ranges of 50 to 150 m ahead of the ship. When the vessel passed over them, some species of fish responded with sudden escape reactions that included lateral avoidance or downward compression of the school. In some rare cases, there have also been reports of fish attraction to traditional and unmanned underwater vessels (Fernandes et al., 2000; Rostad et al., 2006). Though the mechanism for this response is still unknown it is likely related to the type of fish (i.e., predators) and the way they interpret their environment. It is important to note that vessel noise alone may not be the only mechanism for some of these observed responses (De Robertis & Handegard, 2013). Rather, it is likely that other cues (e.g., visual cues, water displacement) play a large role in observed responses of fishes to passing vessels.

As mentioned above, behavioral reactions are variable depending on a number of factors such as (but not limited to) the type of fish, its life history stage, behavior, time of day, location, the sound source (e.g., type of vessel or motor vs. playback of broadband sounds), and the sound propagation characteristics of the water column (Popper et al., 2014; Schwarz & Greer, 1984). Reactions to playbacks of continuous noise or passing vessels generally include basic startle and avoidance responses. Other widely observed responses include: changes in vocalizations; modifications in movement patterns such as changes in vertical distribution in the water column, swim speeds, distance traveled or changes to group cohesion; modified attention or evidence of distractions; effects on foraging success and antipredator responses (e.g., Bracciali et al., 2012; Gendron et al., 2020; Handegard et al., 2015; Jimenez et al., 2020; Krahforst et al., 2016; Luczkovich et al., 2016a; Luczkovich et al., 2016b; Magnhagen et al., 2017; Mauro et al., 2020; Mills et al., 2020; Nedelec et al., 2017a; Neo et al., 2015; Roberts et al., 2016a; Simpson et al., 2015; Stasso et al., 2022; Vieira et al., 2021; Voellmy et al., 2014){Maurer 2023, `#23674}. Both playbacks and actual noise conditions from nearby boats have also resulted in alterations in reproductive and nesting behaviors; signaling and aggression towards potential mates, competitors, and conspecifics; diminished territorial interactions; and reduced parental care behaviors (Amorim et al., 2022; Butler & Maruska, 2020; McCloskey et al., 2020).

Behavioral responses may be dependent on the type of vessel to which a fish is exposed. For example, juvenile damselfish (*Pomacentrus wardi*) exposed to sound from a two-stroke engine resulted in startle responses, reduction in boldness (increased time spent hiding, less time exhibiting exploratory behaviors) and space use (maximum distance ventured from shelter or traveled within the test enclosure). However, damselfish exposed to sound from a four-stroke engine generally displayed similar responses as control fish exposed to ambient noise (e.g., little or no change in boldness) (McCormick et al., 2019). Although the two sound sources were very similar, the vessels powered by the four-stroke engine were of lower intensity (i.e., less energy across all frequencies) compared to vessels powered by the two-stroke engine, which may explain the overall reduced response to this engine type.

Vessel noise may also lead to changes in anti-predator response, but these responses vary by species. During exposures to vessel noise, juvenile Ambon damselfish (*Pomacentrus amboinensis*) and European eels showed slower reaction times and lacked startle responses to predatory attacks. Subsequently these fish showed signs of distraction and increased their risk of predation during both simulated and actual predation experiments (Simpson et al., 2015; Simpson et al., 2016). However, it is not known if these responses would decrease over time as repeated measures were not performed. Juvenile Ambon damselfish showed a reduction in learned anti-predator behaviors likely because of distraction (Ferrari et al., 2018). Spiny chromis (*Acanthochromis polyacanthus*) exposed to chronic (12 consecutive days) boat noise playbacks spent less time feeding and interacting with offspring and displayed increased defensive acts. In addition, offspring survival rates were lower at nests exposed to chronic boat noise playbacks versus those exposed to ambient playbacks (Nedelec et al., 2017b). This suggests that chronic or long-term exposures could have more severe consequences.

In contrast to results from the previous study, larval Atlantic cod showed a stronger anti-predator response and was more difficult to capture during simulated predator attacks (Nedelec et al., 2015). There are also observations of a general lack of response to shipping noise (e.g., Higgs & Humphrey, 2019; Roberts et al., 2016b). Mensinger et al. (2018) found that Australian snapper located in a protected area showed no change in feeding behavior or avoidance during boat passes. Conversely, snapper in areas where fishing occurs startled and ceased feeding behaviors during boat presence suggesting that location and experience have a strong influence on whether fishes react.

Although behavioral responses such as those listed above were often noted during the onset of most sound presentations, most behaviors did not last long, and animals quickly returned to baseline behavior patterns. In fact, in one study with zebrafish, when given the chance to move from a noisy tank (with SPLs reaching 120–140 dB re 1 µPa) to a quieter tank (110 dB re 1 µPa SPL), there was no evidence of avoidance. The fish did not seem to prefer the quieter environment and continued to swim between the two tanks comparable to control sessions (Neo et al., 2015). However, many of these reactions are difficult to extrapolate to real-world conditions due to the captive environment in which testing occurred.

To investigate potential avoidance on a larger scale, Ivanova et al. (2020) tagged Arctic cod and recorded movement and behavior during exposure to noise produced by cargo and cruise ship traffic. Overall, cod increased their horizontal movement outside of their estimated home range when vessels were either present or moving, compared to periods where vessels were absent, indicating periods of potential avoidance. Changes in feeding, travel, and search behaviors were also observed when comparing each sound treatment. The authors note that future studies should continue to investigate whether these observed effects are prolonged or how quickly fish may return to their home range and baseline behaviors.

Most fish species should be able to detect vessel noise due to its low-frequency content and their hearing capabilities. The *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014) suggests that fishes have a high to moderate probability of reacting to nearby vessel noise (i.e., within tens of meters) with decreasing probability of reactions as distance from the source increases (hundreds or more meters).

D.3.4.3 Behavioral Reactions to Impulsive Noise

Most species would show similar behavioral responses across all impulsive sounds, regardless of the source (e.g., weapons noise and explosions). Observations of fish behavioral reactions to impulsive sound sources is largely limited to studies using caged fishes and seismic air guns, with fewer experiments that report reactions to impact pile driving. Commonly reported reactions include startle or alarm responses, changes in swim speed and group cohesion, and in some cases avoidance of the sound source at the onset of some impulsive signals (Fewtrell & McCauley, 2012; Løkkeborg et al., 2012; Pearson et al., 1992; Roberts et al., 2016a; Spiga et al., 2017)(van der Knaap et al., 2022)(Iafrate et al., 2016){McQueen, 2024, `#23675;Kim, 2024, `#23673}. However, these responses may vary greatly depending on the species and context of the exposure.

Several species of caged rockfish (*Sebastes* species), white trevally (*Pseudocaranx dentex*) and pink snapper (all hearing generalists) exhibited startle or alarm reactions to seismic air gun pulses between 180 dB re 1 µPa and 205 dB re 1 µPa peak-to-peak SPL (Pearson et al., 1992). More subtle behavioral changes were noted at lower SPLs, including changes in swim speeds. At the presentation of the sound, all three species moved to the bottom of the experimental enclosure. Both white trevally and pink snapper also exhibited changes in schooling behaviors including changes in group cohesion when exposed to air gun noise (Fewtrell & McCauley, 2012). These behavioral responses were seen during SELs as low as 147 and up to 161 dB re 1 μPa^2s but habituation occurred in all cases, either within a few minutes or within 30 minutes after the final air gun shot (Fewtrell & McCauley, 2012; Pearson et al., 1992).

A study by a research group in the Netherlands conducted an in situ experiment and exposed tagged Atlantic cod to a simulated seismic survey event (Hubert et al., 2020a). Thirty six air guns were utilized in the array and the seismic event was conducted continuously over three-and-a-half days. The location was selected due to high site fidelity of cod in the areas immediately surrounding windfarm turbines in the North Sea and allowed the research group to monitor general movements patterns and overall behavior before, during, and after the survey. Cod were more likely to be inactive during sound exposures and immediately following the surveys, compared to baseline movement patterns (van der Knaap et al., 2021).

Some studies have shown a lack of behavioral reactions to air gun noise. The same research group in the Netherlands exposed cod to playbacks of an air gun in a large net pen (Hubert et al., 2020a). Unlike the study conducted in the North Sea, cod exposed in a net pen showed very little change in behavior or overall use of space within the pen. Herring exposed to an approaching air gun survey (from 27 to 2 km over 6 hours), resulting in single pulses of 125 to 155 dB re 1 μPa^2s SEL, did not react (Pena et al., 2013). Although these levels are similar to those tested in other studies that exhibited responses (Fewtrell & McCauley, 2012), the distance of the exposure to the test enclosure, the slow onset of the sound source, and potential motivation for feeding may have affected the observed response (Pena et al., 2013).

Wardle et al. (2001) observed marine fish on an inshore reef before, during, and after air gun surveys at varying distances. The air guns were calibrated at a peak level of 210 dB re 1 µPa at 16 m and 195 dB re 1 µPa at 109 m from the source. Other than observed startle responses and small changes in the position of adult pollack (*Pollachius pollachius* [a hearing generalist]), when the air gun was located within 10 m of the test site, they found no substantial or permanent changes in the behavior of the fish on the reef (including juvenile saithe [*Pollachius virens*] and cod) throughout the course of the study. A similar study monitored species abundance, composition, behavior and movement patterns over the course of several months to capture long-term responses to a five-day seismic survey (Meekan et al., 2021). This study utilized multiple methods such as underwater baited cameras, tagging, and passive acoustic monitoring to understand each variable under investigation. Overall, the results suggested that there was little, if any, short- or long-term impacts on the demersal fishes (i.e., those that hover slightly above the bottom) from exposure to the full-scale survey.

McQueen et al. (2022) tagged Atlantic cod (*Gadus morhua L.*) to analyze potential responses to a nearby seismic survey. Tagging and analysis was conducted over multiple years (2019-2021) in known spawning locations. Hydrophones and acoustic receivers were placed in two locations; the test site located close to the 'racetrack' where the seismic survey event occurred, and a control site in a nearby area but separated from the racetrack by islands and other features to prevent any sound exposure at this portion of the Study Area. Exposures consisted of a three-hour treatment period with active seismic signals present, and a three-hour control period where no seismic activity was detectable. These periods were repeated in random order over the course of a week in a given test year. SELs varied from 120 to 145 dB re 1 $\mu Pa^2 s$ at the closest point at the treatment site to the seismic survey. Overall, spawning cod did not avoid the noise from the seismic survey and remained at the spawning site despite elevated sound levels. It is likely the cod's preference for the spawning location motivated them to remain in the area despite the presence of the noise.

In contrast, other research on the effects of impulsive seismic survey sound that can last weeks to months has indicated that this level of behavioral response is unlikely (McQueen et al. 2022; Meeken et al. 2021). For example, Meekan et al. (2021) observed no short-term (days) or long-term (months) effects of exposure to the composition, abundance, size structure, behavior, or movement to assemblages of tropical demersal fishes, including hearing specialist species (e.g., Lutjanidae sp.), in Western Australia exposed to noise from a commercial-scale seismic air gun survey with received SELs of up to approximately 180 dB re 1 $\mu Pa^2 \cdot s$. McQueen et al. (2022) examined the responses of spawning cod in the North Sea exposed to seismic air gun noise over two 1-week periods, with fluctuating SELs of up to 145 dB re 1 $\mu Pa^2 \cdot s$, comparable to a full-scale industrial survey 5 to 40 km away (Handegard et al. 2003). Tagged cod in this study were not displaced from spawning grounds (McQueen et al. 2022). McQueen et al. (2022) speculated that strong affinity to selected spawning sites overcame the behavioral effects of stressor exposure. Although the sound source (i.e., seismic air guns) is not analogous to pile driving, they both produce high-intensity, impulsive sound primarily in the 100-Hz or lower frequency bands that overlap the spectral range of cod communication and hearing sensitivity and are informative in the absence of studies assessing the impacts of pile driving to Atlantic cod. Overall, these findings suggest that, although noise exposure during sensitive life stages is a potential concern, disturbances resulting from impulsive sound sources, such as pile driving or seismic air guns, may not necessarily result in adverse effects, such as the complete abandonment of an area for the duration of a spawning season versus temporary displacement or disturbance of Atlantic cod or other hearing specialist species.

Unlike the previously described studies, Slotte et al. (2004) used fishing sonar (38 kHz echo sounder) to monitor behavior and depth of blue whiting (*Micromesistius poutassou*) and Norwegian spring herring (hearing generalists) spawning schools during air gun exposures. They reported that fishes near the air guns appeared to move to greater depths after the air gun exposure compared to their vertical position prior to the air gun usage. Moreover, the abundance of animals 30–50 km away from the air guns increased during seismic activity, suggesting that migrating fish left the zone of seismic activity and did not re-enter the area until the activity ceased. It is unlikely that either species was able to detect the fishing sonar. However, these behavior patterns may have also been influenced by other variables such as motivation for feeding, migration, or other environmental factors (e.g., temperature, salinity).

Alterations in natural behavior patterns due to exposure to pile driving noise reported noted thus far are like those seen in response to seismic surveys. These changes in behavior include startle responses, changes in depth (in both caged and free-swimming subjects), swim speeds, group cohesion, and in attention and anti-predator behaviors, breaching, and directional avoidance (e.g., Hawkins et al., 2014; Kok et al., 2021; Mueller-Blenkle et al., 2010; Neo et al., 2015; Roberts et al., 2016a; Spiga et al., 2017) {Kim, 2024, `#23673}. The severity of responses varies greatly by species and received SPL. For example, Japanese seabass and blackhead seabream reacted to cumulative SELs as low as 138 dB re 1 $\mu Pa^2 \cdot s$ whereas starry flounder showed no significant response to any of the sound exposures tested {Kim, 2024, `#23673}. However, at some higher SPLs (152 - 157 dB re 1 μPa) some free-swimming fishes avoided pile driving noise (Iafrate et al., 2016). The temporal structure of the sound exposure also plays a role in potential responses as demonstrated by slower recovery times in fishes exposed to intermittent sounds (similar to pile driving) compared to continuous exposures {Neo, 2014, `#6665}. Using a baited remote underwater video Roberts et al. (2016a) showed that although multiple species of free swimming fish responded to simulated pile driving recordings, not all responded consistently. In some cases, only one fish would respond while the others continued feeding. In other instances, various individual fish would respond to different strikes. Similar results were reported at an existing windfarm in the Belgian part of the North Sea where tagged free-range Atlantic cod (*Gadus morhua*) showed no significant avoidance response to a largescale pile driving effort and a high variance in measured behavioral responses (van der Knaap et al., 2022). As part of the same experiment, echosounders also indicated that fish abundance and group cohesion changed when pelagic fishes were exposed to pile driving and seismic activities. However, the location of schooling fishes in the water column differed by sound source type, and some of these effects were also noted at the control site (i.e., no sound exposure) which may be explained by other abiotic factors such as seasonality (Kok et al., 2021). The repetition rate of pulses during an exposure may also influence what behaviors are observed during many of these experiments and how quickly these behaviors recovered as opposed to the overall sound pressure or exposure level (Neo et al., 2014).

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), species may react differently to the same sound source depending on a number of variables, such as the animal's life stage or behavioral state (e.g., feeding, mating). Without specific data, the standards committee assumed that fishes with similar hearing capabilities react similarly to all impulsive sounds outside the zone for hearing loss and injury. Observations of fish reactions to large-scale air gun surveys are informative, but not necessarily directly applicable to analyzing impacts from the short-term, intermittent use of all impulsive sources. It is assumed that fish have a high probability of reacting to an impulsive sound source within near and intermediate distances (tens to hundreds of meters), and a decreasing probability of reaction at increasing distances.

D.3.5 Physiological Response

Fishes naturally experience stress within their environment and as part of their life histories. To simulate physiological stress, it is common to test subjects using a variety of stimuli, such as predator vocalizations and anthropogenic noise exposures. The stress response in an animal is a suite of physiological changes that are meant to help an animal mitigate the impact of a stressor. However, if the magnitude and duration of the stress response is too great or too long, then it can have negative consequences to the animal (e.g., decreased immune function, decreased reproduction, increased likelihood of predation). The initial response to a stimulus is a rapid release of stress hormones into the circulatory system, which may cause other responses such as elevated heart rate and blood chemistry changes. A sudden increase in SPL (i.e., presentation of a sound source or acute/short-term exposure), increase in overall background noise levels, or long-duration or continuous exposures have been shown to cause stress, including measurements of biochemical responses and alteration of metabolic rates indicative of a stress response such as increased ventilation and oxygen consumption (e.g., Goetz et al., 2015; Guh et al., 2021; Lara & Vasconcelos, 2021; Madaro et al., 2015; Pickering, 1981; Popper & Hastings, 2009a; Radford et al., 2016; Remage-Healey et al., 2006; Simpson et al., 2015; Simpson et al., 2016; Smith et al., 2004a; Smith et al., 2004b; Spiga et al., 2017; Wysocki et al., 2007; Wysocki et al., 2006){Cui, 2024, `#23672}. However, results from these studies have varied, partially due to the variety of stimuli used in each study, as well as the complicated physiological responses reported.

A common response that has been observed in fishes involves the production of cortisol (a stress hormone) when exposed to sounds such as boat noise, tones, or predator vocalizations. For example, Nichols et al. (2015) exposed the giant kelpfish (*Heterostichus rostratus*), a hearing generalist, to intermittent boat noise and found increased cortisol levels with increased sound levels. Cod exposed to a short-duration upsweep (a tone that sweeps upward) across 100–1,000 Hz showed increases in cortisol levels, which returned to normal one hour post-exposure (Sierra-Flores et al., 2015). Remage-Healey et al. (2006) found elevated cortisol levels in Gulf toadfish (*Opsanus beta* [a hearing generalist]), when exposed to low-frequency bottlenose dolphin sounds, but observed no cortisol change when exposed to low-frequency “pops” produced by snapping shrimp. Butler and Maruska (2020) exposed mouth-brooding freshwater female African cichlids (hearing specialist) to noise within their hearing range (0.1–2.0 kHz) for three hours and then measured the effects of sound on several factors, including cortisol levels. Like other findings, cortisol levels were higher immediately after exposure.

While studies have explored the impacts of vessel noise on hormones, results varied in that some fish species demonstrated increases in cortisol levels (Remage-Healey et al., 2006) and others showed no evidence of change (Mills et al., 2020). One study did show a change in androgen hormone levels in both male and female fish (Mills et al., 2020), however, the impacts of this change are unknown.

Smith et al. (2004b) found no increase in corticosteroid (a class of stress hormones) in goldfish exposed to a continuous, band-limited noise (0.1–10 kHz) at 170 dB re 1 µPa SPL for one month. Wysocki et al. (2007) exposed rainbow trout to continuous band-limited noise with an SPL of about 150 dB re 1 µPa for nine months with no observed stress effects (i.e., growth rates and secondary stress measures via blood samples). Growth rates and effects on the trout’s immune systems were not significantly different from control animals exposed to 110 dB re 1 µPa SPL. In addition, although there was a difference of 10 dB in overall background level and boat activity between test sites, reef fish (*Halichoeres bivittatus*) showed similar levels of whole-body cortisol (Staaterman et al., 2020). This suggests that boat noise, in this context, was not as stressful as handling of the fish for this experiment and contradicts previous conclusions that follow similar study designs.

Kusku (2020) measured respiratory changes as secondary indicators of stress in Nile tilapia (*Oreochromis niloticus*) to determine potential effects of long-term exposure to underwater sound playback, including shipping noise. Fish exposed to noise showed as much as a two-fold increase in respiratory indicators (opercular beat rate and pectoral wing rate) after 10 minutes of sound exposure as compared to controls and pre-exposure rates. Over the next 120 days of continuous sound exposure, respiratory indicators declined steadily and returned to baseline. The authors conclude that the data support habituation of fish to chronic noise exposure.

Zhang et al. (2022) studied the effects of simulated ship noise on liver metabolite production and gene expression of hybrid sturgeon (*Acipenser baerii* × *A. schrencki*). During continuous exposure to underwater noise (12 hours), cell motility increased, while protein synthesis (the process of creating protein in the body) and several metabolic pathways were inhibited. Results suggested that immune response was initiated when exposed to underwater noise stress and that immune-related pathways were activated to protect the normal activities of the fish, despite evidence that underwater noise may have caused some inflammatory responses.

Factors such as early-stage development or survival rates as indicators of stress from a given noise exposure have also been investigated. For example, reef fish embryos exposed to boat noise have demonstrated changes in morphological development and increases in heart rate, another indication of a physiological stress response, although survival rates were unchanged (Fakan & McCormick, 2019; Jain-Schlaepfer et al., 2018). Faria et al. (2022) found evidence of detrimental effects of chronic boat noise on wild Lusitanian toadfish (*Halobatrachus didactylus*) development, and of increased physiological stress assessed by oxidative stress and energy metabolism biomarkers. {Blom, 2024, `#23671@@author-year} also found negative effects on egg and larval development for common gobies (*Pomatoschistus microps*) when exposed to continuous noise, specifically on the yolk sac reserve size. It has been shown that chronic or long-term (days or weeks) exposures of continuous man-made sounds can also lead to a reduction in embryo viability, decreased growth rates, and early mortality including in larvae and fishes infected with parasites (Lara & Vasconcelos, 2021; Masud et al., 2020; Nedelec et al., 2015; Sierra-Flores et al., 2015). Furthermore, Masud et al. (2020) found that guppies exposed to 24 hours of broadband white noise showed increased disease susceptibility compared to those exposed for longer durations (up to 7 days).

Contrary to previous findings, meagre larvae and embryos showed little change in development after exposure to playbacks of boat noise. Specifically, eggs were either provided with either a silent treatment (the controls) or exposed to playbacks of boat noise. On average, playback levels were 25 dB higher than control conditions. Overall, boat noise did not affect measured stress or development responses such as hatching rate, larval size, and yolk sack area. Effects that were noted, such as the size of the lipid droplet area, were small and should be verified with additional data (Trabulo et al., 2023).

Research on physiological stress in fishes due to exposure to explosive sources is limited. Sverdrup et al. (1994) studied levels of stress hormones in Atlantic salmon after exposure to multiple detonations in a laboratory setting. Increases in cortisol and adrenaline were observed following the exposure, with adrenaline values returning to within normal range within 24 hours. This and research on fish responses to other impulsive sources are used to support the analysis.

In summary, fishes may have physiological stress reactions to sounds that they can hear. Generally, stress responses are more likely to occur in the presence of potentially threatening sound sources, such as predator vocalizations, or the sudden onset of impulsive signals rather than from non-impulsive or continuous sources such as vessel noise or sonar. If an exposure is short, the stress responses are typically brief (a few seconds to minutes). In addition, research shows that fishes may habituate to (i.e., learn to tolerate) the noise that is being presented after multiple exposures or longer duration exposures that prove to be non-threatening. However, exposure to chronic noise sources can lead to more severe impacts over time, such as reduced growth rates which can lead to reduced survivability for an individual. It is assumed that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

D.3.6 Direct Injury

Injury to fishes refers to the direct effects on the tissues or organs of a fish. Auditory injuries are generally discussed above in Section D.3.2. No research on the potential injuries from moderate- to low-level noise from vessels, aircraft, and weapons firing is available. However, these sound sources lack the amplitude and energy to cause any direct injury and are not discussed further.

D.3.6.1 Injury due to Sonar and Other Transducers

Non-impulsive sound sources (e.g., sonar, acoustic modems, and sonobuoys) have not been known to cause direct injury or mortality to fish under wild conditions (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007). Potential direct injuries (e.g., barotrauma, hemorrhage or rupture of organs or tissue) from non-impulsive sound sources, such as sonar, are unlikely because of slow rise times, lack of a strong shock wave such as that associated with an explosive, and relatively low peak pressures.

The effects of mid-frequency sonar-like signals (1.5–6.5 kHz) on larval and juvenile Atlantic herring, Atlantic cod, saithe, and spotted wolffish (*Anarhichas minor*) were examined by Jorgensen et al. (2005). Researchers investigated potential effects on survival, development, and behavior in this study. Among fish kept in tanks and observed for one to four weeks after sound exposure, no significant differences in mortality or growth-related parameters between exposed and unexposed groups were observed. Examination of organs and tissues from selected herring experiments did not reveal obvious differences between unexposed and exposed groups. However, two (out of 42) of the herring groups exposed to continuous wave of 189 dB re 1 µPa and 179 dB re 1 µPa SPL had a post-exposure mortality of 19 and 30 percent, respectively. It is not clear if this increased mortality was due to the received level or to other unknown factors, such as exposure to the resonance frequency of the swim bladder (see Section D.1.1.8 for discussion of resonance). Jorgensen et al. (2005) estimated a resonant frequency of 1.8 kHz for herring and saithe ranging in size from 6.3 to 7.0 centimeters, respectively, which lies within the range of frequencies used during sound exposures and, therefore, may explain some of the noted mortalities. Frequency-modulated sonar signals of the same frequency range and intensities did not cause mortality.

Past research has demonstrated that fish species, size, and depth influence the resonant frequency (defined in Section D.1.1.8) of the swim bladder (Løvik & Hovem, 1979; McCartney & Stubbs, 1971). For example, lower frequencies (i.e., generally below 1 kHz) are expected to produce swim bladder resonance in adult fishes from about 10 to 100 centimeters (McCartney & Stubbs, 1971); higher frequencies, greater than 1 kHz, could produce swim bladder resonance in smaller fishes. At resonance, the swim bladder may absorb much of the acoustic energy in the impinging sound wave. It was hypothesized that the resulting oscillations may cause mortality or harm the auditory organs or the swim bladder (Jorgensen et al., 2005; Kvadsheim & Sevaldsen, 2005). However, damage to the swim bladder and to tissues surrounding the swim bladder was not observed in fishes exposed to multiple sonar pulses from approximately 165–195 dB re 1 µPa at their presumed swim bladder resonant frequency (Jorgensen et al., 2005). Fishes may be more susceptible to injury from swim bladder resonance when exposed to continuous signals within the resonant frequency range; although, based on the above studies, injury or mortality from swim bladder resonance under real-world conditions is unlikely.

Hastings (1991); (1995) tested the limits of acoustic exposure on two freshwater fish species. Hastings found "acoustic stunning" (loss of consciousness) in blue gouramis (*Trichogaster trichopterus*) following an eight-minute continuous exposure in captivity to a 150 Hz pure tone of 198 dB re 1 µPa SPL (1995). This species of fish has an air bubble in the mouth cavity directly adjacent to the animal's braincase that may have caused this injury. Hastings (1991); (1995) also found that goldfish, exposed to a 250 Hz continuous wave sound with peak pressures of 204 dB re 1 µPa for two hours, and blue gourami exposed to a 150 Hz continuous wave sound at an SPL of 198 dB re 1 µPa for 0.5 hour did not survive.

To investigate potential injury to the auditory system in fishes, Sapozhnikova et al. (2020) exposed freshwater fish (peled, *Coregonus peled*) to tonal, 300 Hz sound at 176–186 dB re 1 µPa SPL (peak to peak), for up to 18 days. After exposure, cellular changes to hearing structures were assessed. Hair cell bundles of the saccule (one of three otolithic organs in the inner ear) were significantly less dense in sound-exposed fish compared to untreated controls, and changes were only observed for fish exposed longer than five days. Changes to otolith crystal structure and fusion of stereocilia ("hair-like" structures within the inner ear) like that observed after ototoxic antibiotic exposure were also observed after sound exposure, but no direct measurements of hearing loss were taken. The exposure was intended to simulate conditions of common aquaculture systems and therefore may not be applicable to exposures in other environments. Additionally, freshwater fishes are known to have better hearing than marine species, making them more susceptible to auditory impacts. This study does demonstrate some of the more severe physical impacts to the auditory system that could result from extremely long duration exposures to low-frequency tonal signals.

Although these studies (Hastings, 1991; Hastings, 1995; Sapozhnikova et al., 2020) illustrate some of the highest known exposures (long duration exposures to moderately high sound levels) of tonal signals on freshwater fishes with enhanced hearing capabilities, direct comparisons of these results to impacts from transitory signals (e.g., sonar or vessels) should be treated with caution. The conditions of the exposures (e.g., exposure duration, fish's inability to avoid the source) are not synonymous with conditions to an open ocean or coastal environment. Stunning and mortality due to exposure to non-impulsive sound exposure has not been observed in other studies.

Three freshwater species of fish, the rainbow trout, channel catfish, and the hybrid sunfish (*Lepomis* sp.), were exposed to both low- (170 to 320 Hz) and mid-frequency (2.8 to 3.8 kHz) sonar (Kane et al., 2010; Popper et al., 2007). Low-frequency exposures with received SPLs of 193 dB re 1 µPa occurred for either 324 or 648 seconds. Mid-frequency exposures of 210 dB re 1 µPa SPL occurred for 15 seconds. No fish mortality resulted from either experiment. During examination after test exposures, both studies found that none of the subjects showed signs of tissue damage related to exposure (Kane et al., 2010; Popper et al., 2007). As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), although fish have been injured and killed due to intense, long-duration, non-impulsive sound exposures, fish exposed under more realistic conditions have shown no signs of injury. In the absence of other proxies to rely upon, those species tested to date can be used as surrogates for estimating injury in other species exposed to similar sources.

D.3.6.2 Injury due to Impulsive Sound Sources

Non-explosive impulsive sounds, such as those produced by seismic air guns and impact pile driving, may cause injury or mortality in fishes. Mortality and potential damage to the cells of the lateral line have been observed in fish larvae, fry, and embryos after exposure to single shots from a seismic air gun within close proximity to the sound source (0.1–6 m) (Booman et al., 1996; Cox et al., 2012). However, exposure of adult pallid sturgeon (*Scaphirhynchus albus*) and paddlefish (*Polyodon spathula*) to a single shot from an air gun array (four air guns) within similar ranges (6 m) did not result in any signs of mortality within seven days after exposure (Popper et al., 2016). Although injuries occurred in adult fishes, they were like injuries seen in control subjects so there is little evidence that the air gun exposure solely contributed to the observed effects.

Injuries, such as ruptured swim bladders, hematomas, and hemorrhaging of other gas-filled organs, have been reported in fish exposed to a large number of simulated impact pile driving strikes with cumulative SELs up to 219 dB re 1 μPa^2s under highly controlled settings where fish were unable to avoid the source (Casper et al., 2013a; Casper et al., 2012b; Casper et al., 2013b; Halvorsen et al., 2012a; Halvorsen et al., 2011, 2012b). However, it is important to note that these studies exposed fish to 900 or more strikes as the studies aimed to evaluate the equal energy hypothesis, which suggests that the effects of a large single pulse of energy is equivalent to the effects of energy received from many smaller pulses (as discussed in Smith & Gilley, 2008). Halvorsen et al. (2011) and Casper et al. (2017) propose that the equal energy hypothesis does not apply to effects of pile driving. Specifically, Casper et al. (2017) found the amount of energy in each pile strike had a larger influence on resulting injuries than the number of strikes even when the SEL was equal. For example, hybrid striped bass (white bass x striped bass) exposed to fewer strikes with higher single strike sound exposure values resulted in a higher number of, and more severe, injuries than bass exposed to an equivalent cumulative SEL that contained more strikes with lower single strike sound exposure values. This is important to consider when comparing data from pile driving studies to potential effects from an explosion. Although single strike peak SPLs were measured during these experiments (at average levels of 207 dB re 1 µPa), the injuries were only observed during exposures to multiple strikes; therefore, it is anticipated that a peak value much higher than the reported values would be required to lead to injury in fishes exposed to a single strike or explosion.

The studies discussed in the paragraph above included species both with and without swim bladders. Most fishes that exhibited injuries were those with swim bladders. Lake sturgeon (*Acipenser fulvescens*), a physostomous fish, was found to be less susceptible to injury from impulsive sources than Nile tilapia or hybrid striped bass, both of which are physoclistous fishes (Casper et al., 2017; Halvorsen et al., 2012a). Halvorsen et al. (2012a) proposed that the difference in results is likely due to the type of swim bladder present in each species. Physostomous fishes have an open duct connecting the swim bladder to their esophagus and may be able to quickly adjust the amount of gas in their body by gulping or releasing air. Physoclistous fishes do not have this duct; instead, special tissues or glands regulate gas pressure in the swim bladder and are unable to react quickly enough to reduce pressure appreciably in response to an impulsive sound stressor. There were no mortalities reported during these experiments, and in the studies where recovery was observed, most exposure related injuries healed within a few days in a laboratory setting. In many of these controlled studies, neutral buoyancy was determined in the fishes prior to exposure to the simulated pile driving. However, fishes with similar physiology to those described in these studies that are exposed to actual pile driving activities may not be neutrally buoyant at the onset of an exposure and therefore may show varying levels of injury depending on their state of buoyancy.

By exposing caged juvenile European sea bass (*Dicentrarchus labrax*) to actual pile driving operations, Debusschere et al. (2014) confirmed the results discussed above. No differences in mortality were found between control and experimental groups (215–222 dB re 1 μPa^2s SEL), and many of the same types of injuries occurred (Casper et al., 2013a; Casper et al., 2012b; Casper et al., 2013b; Halvorsen et al., 2012a; Halvorsen et al., 2011, 2012b).

Other potential effects from exposure to impulsive sound sources include bubble formation and neurotrauma. It is speculated that high SPLs may cause bubbles to form from micronuclei in the blood stream or other tissues of animals, possibly causing embolism damage (Hastings & Popper, 2005). Fishes have small capillaries where these bubbles could be caught, leading to vessel rupture and internal bleeding. It has also been speculated that this phenomena could take place in the eyes of fish due to potentially high gas saturation within the eye tissues (Popper & Hastings, 2009b). Additional research is necessary to verify if these speculations apply to exposures to non-impulsive sources such as sonars. These phenomena have not been well studied in fishes and are difficult to recreate under real-world conditions.

As summarized in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), exposure to high intensity and long duration impact pile driving or air gun shots has not caused mortality, and fishes typically recovered from injuries in controlled laboratory settings. Barring other proxies to rely upon, species tested to date can be used as surrogates for investigating injury in other species exposed to similar sources (Popper et al., 2014).

D.3.6.3 Injury due to Explosions

The blast wave from an explosion is lethal to fishes at close range, causing massive organ and tissue damage (Keevin & Hempen, 1997). At greater distance from the detonation point, the extent of mortality or injury depends on many factors including fish size, body shape, depth, physical condition of the fish, and, perhaps most importantly, the presence of a swim bladder. In general, fishes without swim bladders have been shown to be more resilient to explosives compared to those with swim bladders (Gaspin, 1975; Gaspin et al., 1976; Goertner et al., 1994). At the same distance from the source, larger fishes and those with elongated forms that are round in cross-section were generally less susceptible to death or injury than smaller fishes and deep-bodied forms, and fishes oriented sideways to the blast suffer the greatest impact (O'Keeffe, 1984; O'Keeffe & Young, 1984; Wiley et al., 1981; Yelverton et al., 1975).

If a fish is close to an explosive detonation, the exposure to rapidly changing high pressure levels can cause barotrauma. Barotrauma is injury due to a sudden difference in pressure between an air space inside the body and the surrounding water and tissues. Rapid compression followed by rapid expansion of airspaces, such as the swim bladder, can damage surrounding tissues and result in the rupture of the airspace itself. The swim bladder is the primary site of damage from explosives (Dahl et al., 2020; Wright, 1982; Yelverton et al., 1975). Gas-filled swim bladders resonate at different frequencies than surrounding tissue and can be torn by rapid oscillation between high- and low-pressure waves (Goertner, 1978). Swim bladders are a characteristic of most bony fishes, with the notable exception of some flatfishes (e.g., halibut). Sharks and rays are examples of cartilaginous fishes which lack a swim bladder. Small airspaces, such as micro-bubbles that may be present in gill structures, could also be susceptible to oscillation when exposed to the rapid pressure increases caused by an explosion. This may have caused the bleeding observed on gill structures of some fish exposed to explosions (Goertner et al., 1994). Sudden very high pressures can also cause damage at tissue interfaces due to the way pressure waves travel differently through tissues with different densities. Rapidly oscillating pressure waves might rupture the swim bladder, kidney, liver, and spleen and cause venous hemorrhaging (Dahl et al., 2020; Jenkins et al., 2022; Keevin & Hempen, 1997).

Several studies have exposed fish to explosives and examined various metrics in relation to injury susceptibility. Sverdrup et al. (1994) exposed Atlantic salmon in a laboratory setting to repeated shock pressures of around 2 megapascals (300 psi or 246 dB re 1 µPa peak) without any immediate or delayed mortality after a week. Hubbs and Rechnitzer (1952) exposed fish to underwater detonations placed either on the seafloor or buried at various depths along an underwater canyon in La Jolla, CA. Data from this experiment showed that when near the surface, fishes began to exhibit injuries around peak pressure exposures of 40–70 psi (229 to 234 dB re 1 µPa peak). However, near the bottom (all water depths were less than 100 feet [ft.]) fish exposed to pressures over twice as high exhibited no sign of injury. Yelverton et al. (1975) found that peak pressure was not correlated to injury susceptibility; instead, injury susceptibility of swim bladder fish at shallow depths (10 ft. or less) was correlated to the metric of positive impulse (pascal seconds [Pa-s]), which takes into account the positive peak pressure, the duration of the positive pressure exposure, and fish mass, with smaller fish being more susceptible than larger fishes.

Three experiments reported the effects of underwater explosions on Pacific sardines (*Sardinops sagax*) and Pacific mackerel (*Scomber japonicus*) to underwater detonations of C4 explosives at the same general test site off the coast of California, though the experiments took place during different years (Dahl et al., 2020; Jenkins et al., 2022){Bowman, 2024, `#23443}. In all efforts, fish were stationed at various distances (out to approximately 800 m) prior to the explosion, in addition to a control group that was not exposed. Necropsies following explosions observed statistically significant injuries, including fat hematoma, kidney rupture, swim bladder bruising and rupture, and reproductive blood vessel rupture. Injuries decreased with increasing distance from the explosion, and swim bladder injuries were the most prevalent. While most significant injuries were consistently present at close range (less than 50 m, approximately 240 dB re 1 µPa peak) with decreasing proportion of injury farther from the source in both studies, Dahl et al. (2020) found inconsistent findings at the 50–125 m range (approximately 240 – 232 dB re 1 µPa peak). The inconsistency in observed physical damage at this distance from the detonation was due to possible acoustic refraction effects, including waveform paths that were bottom reflected, surface reflected, or a combination of both.

Some fish mortality was observed during the Jenkins et al. (2022) experiment, in a portion of cages at or within 157 m (received level of 231 dB re 1 µPa peak) of the explosion. Additionally, unique video footage from a subset of treatment groups showed most fish at or within 257 m (a peak SPL of 224 dB re 1 µPa) were stunned (immobilized) immediately following exposure. To the contrary, all but one Pacific mackerel survived three hours post exposure in the final of this series of experiments {Bowman, 2024, `#23443}. {Bowman, 2024, `#23443@@author-year} also looked at hair cell bundle densities post exposure. Densities were significantly different between treatment groups, with the most hair cell lost for fish closest to the explosive (150m; peak SPL of 226-232 dB re 1µPa). Unlike Yelverton et al. (1975), the statistical model demonstrated that while all three acoustic measures were good predictors of injury, peak pressure and SEL were better predictors of injury than pressure impulse.

Multiple fishes with a swim bladder were exposed to explosions of varying sizes across a variety of depths (Gaspin, 1975; Gaspin et al., 1976). Subsequently, a swim bladder oscillation model was developed, which showed that the severity of injury observed in those tests could be correlated to the extent of swim bladder expansion and contraction predicted to have been induced by exposure to the explosive blasts (Goertner, 1978; Wiley et al., 1981). Per this model, the degree of swim bladder oscillation is affected by ambient pressure (i.e., depth of fish), peak pressure of the explosive, duration of the pressure exposure, and exposure to surface rarefaction (negative pressure) waves. The maximum potential for injury is predicted to occur where the surface reflected rarefaction (negative) pressure wave arrives coincident with the moment of maximum compression of the swim bladder caused by exposure to the direct positive blast pressure wave, resulting in a subsequent maximum expansion of the swim bladder. Goertner (1978) and Wiley et al. (1981) found that their swim bladder oscillation model explained the injury data in the Yelverton et al. (1975) exposure study and that the Yelverton and Richmond (1981) impulse parameter was applicable only to fishes at shallow enough depths to experience less than one swim bladder oscillation before being exposed to the following surface rarefaction wave.

O'Keeffe (1984) provides calculations and contour plots that allow estimation of the range to potential effects of explosions at or near the surface of the water on fish possessing swim bladders using the damage prediction model developed by Goertner (1978). O'Keeffe (1984) parameters include the charge weight, depth of burst, and the size and depth of the fish, but the estimated ranges do not consider unique propagation environments that could reduce or increase the range to effect. Based on these calculations, it was suggested that fish at greater depths and near the surface are predicted to be less likely to be injured because geometries of the exposures would limit the amplitude of swim bladder oscillations. In contrast, detonations at or near the surface, like most proposed activities that utilize bombs, missiles, and gunfire, would result in surface blow off (i.e., loss of energy into the air), resulting in lower overall ranges to effects.

Studies that have documented caged fishes killed during planned underwater explosions indicate that most fish that die do so within one to four hours, after exposure and almost all die within 24-hours (Yelverton et al., 1975). Mortality in free-swimming (uncaged) fishes may be higher due to increased susceptibility to predation. Fitch and Young (1948) found that the type of free-swimming fish killed changed when blasting was repeated at the same location within 24 hours of previous blasting. They observed that most fish killed on the second day were scavengers, presumably attracted by the victims of the previous day’s blasts.

Fitch and Young (1948) also investigated whether a significant portion of fish killed would have sunk and not been observed at the surface. Comparisons of the numbers of fish observed dead at the surface and at the bottom in the same affected area after an explosion showed that fish found dead on the bottom comprised less than 10 percent of the total observed mortality. Gitschlag et al. (2000) conducted a more detailed study of both floating fishes and those that were sinking or lying on the bottom after explosive removal of nine oil platforms in the northern Gulf of Mexico. Results were highly variable. They found that 3–87 percent (46 percent average) of the red snapper killed during a blast might float to the surface. Currents, winds, and predation by seabirds or other fishes may be some of the reasons that the magnitude of fish mortality may not have been accurately captured.

There have been few studies of the impact of underwater explosives on early life stages of fish (eggs, larvae, juveniles). Fitch and Young (1948) reported mortality of larval anchovies scooped opportunistically during underwater blasting off the coast of California. Detonations used during these operations varied in size (from 10 to 160 pounds), with some explosives placed just beneath the water’s surface and others buried under the seafloor. Although the authors mention observations of live fish within the “lethal range” of these detonations, specific distances and search patterns were not provided. Another experiment reported dead anchovy and smelt larvae within approximately 50 m of buried charges weighing from 90 to 180 pounds in a shallow water channel during a pipeline construction project (Nix & Chapman, 1985). Although this provides useful insight into potential impacts to fishes from explosives, acoustic measures were not taken during either of these studies to correlate mortality with received levels. Similar to adult fishes, the presence of a swim bladder contributes to shock wave-induced internal damage in larval and juvenile fish (Settle et al., 2002). Explosive shock wave injury to internal organs of larval pinfish (*Lagodon rhomboids*) and spot (*Leistomus xanthurus*) exposed at shallow depths was documented at impulse levels similar to those predicted by Yelverton et al. (1975) for very small fish and provide the lowest measured received level that injuries have been observed in larval fish (peak SPLs of 220 dB re 1 µPa) (Govoni et al., 2003; Govoni et al., 2008; Settle et al., 2002). Researchers have suggested that egg mortality may be correlated with peak particle velocity exposure [i.e., the localized movement or shaking of water particles, as opposed to the velocity of the blast wave (Faulkner et al., 2006; Faulkner et al., 2008; Jensen, 2003)], although sufficient data from direct explosive exposures is not available.

Observations of the inner ear and lateral line across fishes exposed to explosives are lacking. Smith et al. (2022) provide the first examination of the physical effects of underwater explosions on the inner ear of Pacific mackerel (*Scomber japonicus*). Results showed varying amounts of hair cell loss as well as evidence of hair cell shearing and even holes in the epithelial tissue along the saccule related to the explosive exposure. Significant impacts were observed starting at peak SPLs of 220 dB re 1 µPa. Additional impacts on these sensory system organs have been observed during exposure to other impulsive sources such as air guns and playbacks of impact pile driving noise, which would indicate that similar effects may be possible in fishes exposed to explosions (Booman et al., 1996; Casper et al., 2013a; McCauley et al., 2003). Rapid pressure changes could cause mechanical damage to sensitive ear structures due to differential movements of the otolithic structures. Bleeding near otolithic structures was the most commonly observed injury in non-swim bladder fish exposed to a close explosive charge (Goertner et al., 1994). Additional research is needed to understand the potential for sensory cell damage from explosive exposures, the severity and implication of such affects for individual fish, and at what sound levels these impacts may occur.

As summarized by the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014), exposure to explosive energy poses the greatest potential threat for injury and mortality in marine fishes. Fishes with a swim bladder are more susceptible to injury than fishes without a swim bladder. The susceptibility also probably varies with size and depth of both the detonation and the fish. Fish larvae or juvenile fish may be more susceptible to injury from exposure to explosives.

D.3.7 Long-Term Consequences

Mortality removes an individual fish from the population and injury can reduce the fitness of an individual. Fishes with injuries from any sound exposure may not survive in the wild due to harsher conditions and risk of predation. They may also have long-term competitive disadvantages for prey and mates, relative to uninjured individuals of the same species. Few studies have been conducted on any long-term consequences from repeated hearing loss, stress, or behavioral reactions in fishes due to exposure to loud sounds (Hawkins et al., 2015; Popper & Hastings, 2009a; Popper et al., 2014).

Repeated exposures of an individual to multiple sound-producing activities over a season, year, or life stage could cause reactions with costs that can accumulate over time to cause long-term consequences for the individual. These long-term consequences may affect the survivability of the individual, or if impacting enough individuals may have population-level effects, including alteration from migration paths, avoidance of important habitat, or even cessation of foraging or reproductive behavior (Hawkins et al., 2015). For example, {Blom, 2024, `#23671} reported significant decreases in brood size, brood area, brood density, and yolk sack reserve for the common goby when exposed to continuous, low-frequency broadband noise during breeding and egg development. Continued or increased amounts of vessel noise exposure on these populations could therefore lead to lower population growth rates and larval survival overall, potentially having long-term population effects. Additionally, Soudijn et al. (2020) attempted to design a theoretical population consequences model without quantitative data on SELs. Atlantic cod energy expenditure, food intake, mortality rate, and reproductive output were analyzed to assess cod's potential impacts from sound exposure. The model predicted decreased food intake, increased energy expenditure, and decreased population growth rate because of increased continuous noise. Models such as these are common among other taxa and often come to similar conclusions. Conversely, some animals may habituate to or become tolerant of repeated exposures over time, learning to ignore a stimulus that in the past has not accompanied any overt threat. In fact, Sivle et al. (2016a) and Sivle et al. (2015a) predicted that exposures to sonar at the maximum levels tested would only result in short-term disturbance and would not likely affect the overall population in sensitive fishes such as Atlantic herring. Additional research is needed to understand the complex relationship of sound exposure to potential long-term consequences to individuals and populations.

D.4 Marine Mammals

This section describes general effects to marine mammals from exposure to acoustic sources.

D.4.1 Hearing

The typical mammalian ear has an outer ear that collects and transfers sound to the eardrum and then to the middle ear (Fay & Popper, 1994; Rosowski, 1994). The middle ear contains bones that amplify and transfer acoustic energy to the inner ear, which contains sensory cells (called hair cells) that transform acoustic energy into electrical signals. Those electrical signals are then carried by the auditory nerve to the brain (Møller, 2013).

All marine mammals display some modifications to the typical mammalian ear; furthermore, there are differences between the hearing of marine mammals that are fully aquatic and those that are amphibious – or live partially out of the water (Wartzok & Ketten, 1999). Marine mammals with an amphibious ear include the marine carnivores: pinnipeds, sea otters, and polar bears (Ghoul & Reichmuth, 2014b; Owen & Bowles, 2011; Reichmuth et al., 2013). Outer ear adaptations in this group include outer ears that are reduced or absent, and in seals, specialized tissues that act as valves to seal off water from entering the ear canal when submerged (Wartzok & Ketten, 1999). In marine mammals with a fully aquatic ear (cetaceans and sirenians), bone and fat channels in the head conduct sound to the ear; while the ear canal still exists, it is narrow and sealed, and outer ears are absent (Castellini et al., 2016; Ketten, 1998) (see Figure D.4-1). These adaptations reflect specializations for hearing in both air and water for amphibious marine mammals, and for hearing in water for fully aquatic marine mammals.

Notes: The amphibious California sea lion outer ear is reduced compared to terrestrial mammals, while the harbor seal lacks an outer ear and has specialized valve-like tissue to close off the ear canal from water. The aquatic bottlenose dolphin lacks an outer ear and has a drastically reduced pinhole-like ear canal yet has specialized hearing for underwater sounds.
Sources: https://pediaa.com/difference-between-seal-and-sea-lion, https://www.shutterstock.com/pic.mhtml?id=69136297

Figure D.4-1: Examples of Marine Mammal Ears

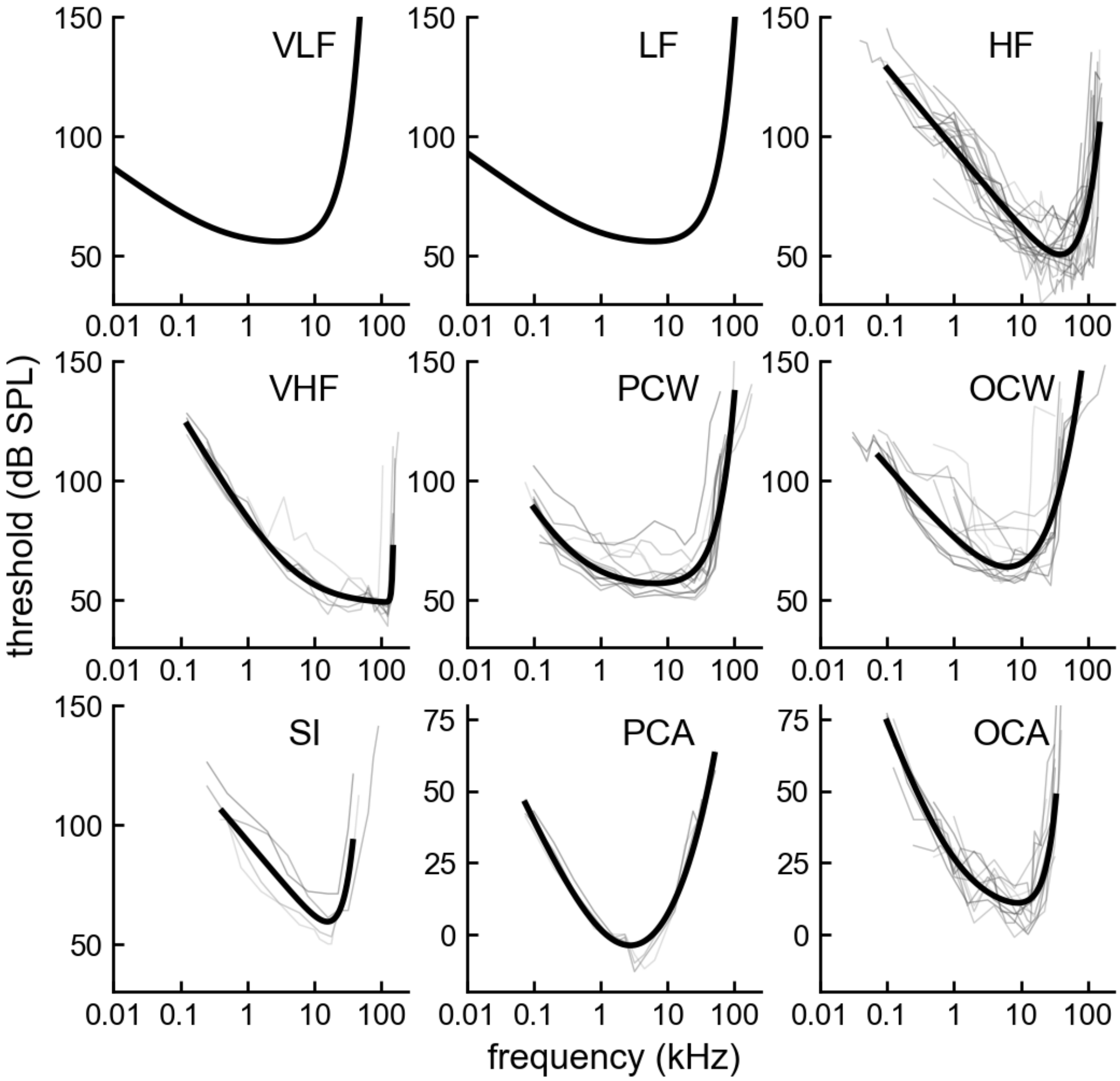
Marine mammal audiograms, like those of terrestrial mammals, typically have a “U-shape,” with a frequency region of best hearing sensitivity at the bottom of the “U” and a progressive decrease in sensitivity outside of the range of best hearing (Southall et al., 2019c) (see Figure D.1-8).

Direct measurements of hearing sensitivity exist for about a quarter of the nearly 130 species of marine mammals. Marine mammals are arranged into the following functional hearing groups based on their generalized hearing sensitivities: very high-frequency cetaceans (VHF group: porpoises, Kogia spp.), high-frequency cetaceans (HF group: delphinids, beaked whales, sperm whales), low-frequency cetaceans (LF group: mysticetes), very low-frequency cetaceans (VLF group: larger mysticetes), sirenians (SI group: manatees), otariids and other non-phocid marine carnivores in water and air (OCW and OCA groups: sea lions, otters), and phocids in water and air (PCW and PCA groups: true seals) (Southall et al., 2019c). Representative composite audiograms (U.S. Department of the Navy, 2024a) have been created for each functional hearing group using audiograms from published literature (see Figure D.4-2).

Since the composite audiograms were developed for this analysis, Houser et al. (2022) published new AEP audiograms for stranded odontocetes of six species for which no audiograms had previously existed: dwarf sperm whale (*Kogia sima*), pygmy sperm whale (*Kogia breviceps*), northern right whale dolphin (*Lissodelphis borealis*), melon-headed whale (*Peponocephala electra*), long-beaked common dolphin (*Delphinus capensis*), and Atlantic spotted dolphin (*Stenella frontalis*). Hearing data was also provided on the pygmy killer whale (*Feresa attenuata*). The audiograms had frequency ranges, shapes, and upper frequency limits that were generally consistent with the hearing groups in which these species are categorized (see Table 2 in U.S. Department of the Navy, 2024a).

For marine mammals that are impractical to test or have limited hearing data (e.g., mysticete whales and rare species), some aspects of hearing can be estimated from anatomical structures, frequency content of vocalizations, behavioral responses to sound and inferences from related species (U.S. Department of the Navy, 2024a). For example, behavioral responses of gray whales suggests that they can hear 21 - 25 kHz signals (Frankel & Stein, 2020). The only hearing measurement in a mysticete (minke whale) Houser et al. (2024) suggests that LF cetaceans have a upper-frequency limit of hearing between 45 and 90 kHz. Although there have been no direct measurements of hearing sensitivity in larger mysticetes (VLF hearing group), an audible frequency range of approximately 10 Hz to 30 kHz has been estimated from measured vocalization frequencies, observed reactions to playback of sounds, and anatomical analyses of the auditory system (Cranford & Krysl, 2015; Houser et al., 2001a). See the technical report titled *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase IV)* (U.S. Department of the Navy, 2024a) for a complete description of marine mammal composite audiograms.

Research has shown that hearing in marine mammals is directional: the relative angle between the sound source location and the animal's position affects the hearing threshold. This is important because how an animal perceives sound is dependent on the hearing threshold. For example, a sound presented from directly in front of an animal might be heard clearly, while the same sound presented from directly behind an animal might not be heard. For bottlenose dolphins, hearing sensitivity becomes more directional as the sound frequency increases, with the greatest sensitivity to sounds presented in front and below the dolphin (Accomando et al., 2020; Au & Moore, 1984). Hearing sensitivity is asymmetrical in the vertical and horizontal planes, which might be beneficial for localizing a sound source. Harbor porpoises and belugas exhibit direction-dependent hearing, but to a lesser degree than the dolphin (Kastelein et al., 2019b; Kastelein et al., 2005a; Popov & Supin, 2009). Based on experiments in harbor seals, phocids likely have well-developed directional hearing for biologically relevant sounds (Byl et al., 2016; Byl et al., 2019). Directional hearing is important to consider when assessing masking effects.



Notes: For hearing in water (top two rows) and in air (bottom row, phocids and otariids only). VLF = very low frequency; LF = low frequency; HF = high frequency; VHF = very high frequency; PCW = phocids in water; OCW = otariids and other non-phocid marine carnivores in water; SI = sirenians in water; OCA = otariids and other non-phocid marine carnivores in air; PCA = phocids in air

Figure D.4-2: Composite Audiograms used in Marine Mammal Hearing Criteria and Thresholds

D.4.2 Acoustic Signaling

Like the diversity of hearing capabilities among species, the wide variety of acoustic signals used in communication and echolocation is reflective of the diverse characteristics of marine mammal species. Detailed reviews of sounds generated by marine mammals are available, see Chapter 7 of Richardson et al. (1995b) and Table 4-1 in Wartzok and Ketten (1999). A general division can be drawn between lower frequency communication signals including vocalizations that are produced by all marine mammals, and the specific, high-frequency echolocation (i.e., biosonar) signals that are used by odontocetes to sense their environment. The general types and frequency characteristics of marine mammal vocalizations are described in Table D.3-1.

Table D.4-1: Marine Mammal Vocalizations

Signal type	*Description*	*Marine mammal group(s)*	*Frequency range[1]*
Echolocation	Broadband, short-duration, high-source level clicks serving a primarily sensory function with a secondary communication function[2].	HF & VHF cetaceans	20 – 160 kHz
Communication	Tonal (e.g., whistles) and non-tonal (e.g., grunts) with a wide variety of durations and source levels and serving primarily for communication (e.g., mating, mother-calf contact, group cohesion/coordination, and other social functions).	VLF cetaceans	0.01 – 0.4 kHz
		LF cetaceans	0.1 – 4 kHz
		HF & VHF cetaceans	4 – 30 kHz
		Sirenians	0.6 – 16 kHz
		Pinnipeds (phocids, otariids)	0.1 – 30 kHz
		Otters	3 – 5 kHz
		Polar bears	0.2 – 1 kHz

[1]The frequencies near maximum energy based on Table 4-1 in Wartzok and Ketten (1999).
[2] Sperm whales use clicks to echolocate and specific click patterns primarily to communicate. Some other species might also use click patterns that function primarily to communicate.

D.4.2.1 Communication

Communication sounds have crucial functions including social (e.g., mating), maintaining mother-calf contact, group cohesion, feeding, and other purposes. Communication signals include calls (i.e., vocalizations) and sounds produced by non-vocal behaviors such as tail/fluke slaps on the water surface or clapping the jaw. Vocalizations might have a tonal quality or pitch resulting from a prominent fundamental frequency, such as whistles in some odontocetes and sirenian calls (Brady et al., 2021), or they might be less tonal because of energy distributed across a wide frequency range such as grunts produced by marine carnivores like pinnipeds. Aerial vocalizations are produced by pinnipeds, otters, and polar bears. The acoustic characteristics of communication signals of marine mammals are quite diverse but can be generally classified as having dominant energy at frequencies between approximately 20 Hz and 30 kHz (Richardson et al., 1995b; Wartzok & Ketten, 1999).

Of note are the lower frequency calls of mysticete whales that range from tens of Hz to several kHz and have source levels of approximately 150–200 dB re 1 µPa. Typically, mysticete calls have fundamental frequencies below 200 Hz. Fin whales and blue whales make exceptionally low frequency calls (10 -16 Hz), while humpback whales make higher frequency calls having harmonics that exceed 20 kHz, (Au et al., 2006; Cummings & Thompson, 1971; Edds-Walton, 1997; Širović et al., 2007; Stimpert et al., 2007; Wartzok & Ketten, 1999). These calls most likely serve social functions such as interspecific attraction or detection over long distances but could serve an orientation function as well (Frazer & Mercado, 2000; Green, 1994; Green et al., 1994; Mercado, 2021; Richardson et al., 1995b).

D.4.2.2 Echolocation

Odontocete cetaceans generate short-duration (50–200 microseconds), high-frequency (10 – 200 kHz peak frequency), specialized echolocation clicks (e.g., biosonar) used to detect, localize, and characterize underwater objects (Au, 1993; Wartzok & Ketten, 1999). This process is essential for hunting, including searching, tracking, and capturing prey. Echolocation clicks are often more intense than communicative signals, with reported source levels as high as 229 dB re 1 µPa peak-to-peak (Au et al., 1974). The echolocation clicks of very high-frequency cetaceans (e.g., porpoises) are narrower in bandwidth (i.e., the difference between the upper and lower frequencies in a sound) and higher in frequency than those of high-frequency cetaceans (Madsen et al., 2005; Villadsgaard et al., 2007). The specific characteristics of echolocation signals such as their repetition patterns and peak frequency can be used to identify species (Baumann-Pickering et al., 2013).

Echolocation can serve communicative functions even though clicks are not usually produced for this purpose by most odontocetes. For example, eavesdropping animals may hear rapid echolocation clicks and other sounds associated with feeding to find food or avoid predators, and sperm whale clicks may reveal the size or general characteristics of the clicking individual. However, some types of clicks or patterns of clicks are thought to be produced for the purpose of communication. For example, click patterns called codas are communicative vocalizations produced by sperm whales (Jacobs et al., 2024; Richardson et al., 1995b; Watkins & Schevill, 1977).

D.4.2.3 Relationship between Hearing and Vocalization

In general, frequency ranges of sounds produced by a species lie within the audible frequency range for that species (i.e., animals vocalize within their audible frequency range). However, auditory frequency range and vocalization frequencies do not perfectly align. For example, odontocete echolocation clicks contain a broad range of frequencies, and not all the frequency content is necessarily heard by the individual that emitted the click. The frequency range of vocalization in a species can therefore be used to infer some characteristics of their hearing capabilities; however, caution must be taken when considering vocalization frequencies alone in predicting the hearing capabilities of species for which data are absent or limited such as mysticete whales.

Aspects of vocalization and hearing sensitivity are subject to evolutionary pressures that are not solely related to communication within the species. For example, hearing and vocalization is influenced by the need to detect or avoid threats such as predators (e.g., Deecke et al., 2002) and listening for prey-generated sounds. Additionally, high-frequency hearing is advantageous to animals with small heads because it facilitates sound localization based on differences in sound levels at each ear (Heffner & Heffner, 1982). These factors might be partially responsible for the difference in best hearing thresholds and dominant vocalization frequencies in some species of marine mammals (e.g., Steller sea lions, Mulsow & Reichmuth, 2010).

D.4.3 Hearing Loss and Auditory Injury

All mammals experience normal age-related hearing loss (presbycusis), which is a progressive reduction in the ability to hear higher frequencies that spreads to lower frequencies over time. This type of hearing loss is due to the loss of sensory cells in the inner ear and degeneration of the pathways that connect the ear to the brain. Age-related hearing loss occurs over a lifetime and is distinct from acute noise-induced hearing loss (Møller, 2013).

Noise-induced hearing loss can be temporary (i.e., temporary threshold shift, or TTS) or permanent (i.e., permanent threshold shift, or PTS), and higher-level sound exposures are more likely to cause PTS or other auditory injury. For marine mammals, auditory injury (AINJ) is considered to be possible when sound exposures are sufficient to produce 40 dB of TTS measured approximately four minutes after exposure (U.S. Department of the Navy, 2024a).

Numerous studies have directly examined noise-induced hearing loss in marine mammals. In these studies, hearing thresholds were measured in marine mammals before and after exposure to intense sounds. The difference between the post-exposure and pre-exposure hearing thresholds is used to determine the amount of TTS in dB that was produced as a result of the sound exposure. The data from these studies is detailed in (U.S. Department of the Navy, 2024a) and the major findings are outlined in Table D.4-2.

Table D.4-2: Major Findings from Studies of Threshold Shift in Marine Mammals

Major Finding	*Supporting Scientific Studies*
Hearing test method	
The method used to test hearing may affect the resulting amount of measured temporary threshold shift (TTS), with auditory evoked potential measures producing larger amounts of TTS compared to behavioral measures.	Finneran (2015); Finneran et al. (2007)
Effect of frequency and sound pressure level (SPL)	
Sound exposures of a narrow frequency range can produce TTS over a large frequency range.	Finneran et al. (2007); Kastelein et al. (2020a); Kastelein et al. (2019d); Kastelein et al. (2019f); Mooney et al. (2009a); Nachtigall et al. (2004); Popov et al. (2013); Popov et al. (2011); Reichmuth et al. (2019); Schlundt et al. (2000)
As the exposure SPL increases, the frequency at which the maximum TTS occurs also increases.	Finneran et al. (2007); Kastelein et al. (2020a); Kastelein et al. (2019d); Kastelein et al. (2019f); Kastelein et al. (2014a); Mooney et al. (2009a); Nachtigall et al. (2004); Popov et al. (2013); Popov et al. (2011); Reichmuth et al. (2019); Schlundt et al. (2000)
Sounds at frequencies well below the region of best sensitivity are generally less hazardous than those near the region of best sensitivity.	Finneran and Schlundt (2013); Kastelein et al. (2020a); Kastelein et al. (2019d); Kastelein et al. (2019f); (Gransier & Kastelein, 2024)
Effect of exposure duration, sound exposure level (SEL), and multiple exposures	
The amount of TTS increases with exposure SPL and duration and is correlated with SEL, but duration of the exposure has a more significant effect on TTS than would be predicted based on SEL alone. As the exposure duration increases, the relationship between TTS and SEL begins to break down.	Finneran et al. (2010b); Kastak et al. (2007); Kastak et al. (2005); Kastelein et al. (2014a); Mooney et al. (2009a); Popov et al. (2014); (Gransier & Kastelein, 2024)
TTS can accumulate across multiple exposures, but the resulting TTS will be less than the TTS from a single, continuous exposure with the same SEL. This means that TTS predictions based on the total, cumulative SEL will overestimate the amount of TTS from intermittent exposures such as sonars and impulsive sources[1].	Finneran et al. (2010b); Finneran et al. (2000); Finneran et al. (2002); Kastelein et al. (2015a); Kastelein et al. (2018a); Kastelein et al. (2014a); Mooney et al. (2009b); Reichmuth et al. (2016)
Growth of TTS and occurrence of permanent threshold shift (PTS)	
Gradual growth of TTS with increased levels of SEL typically occurs before onset of PTS. However, it is possible for PTS to occur without observing gradual growth of TTS or behavioral changes.	Reichmuth et al. (2019)
Recovery from TTS over time	

Major Finding	*Supporting Scientific Studies*
The time required for complete recovery of hearing depends on the magnitude of the initial shift; for relatively small shifts recovery may be complete in a few minutes, while large shifts may require several days for recovery. Recovery times are consistent for similar-magnitude TTS, regardless of the type of sound exposure (impulsive, continuous noise band, or sinusoidal wave).	Finneran et al. (2010a, 2010b); Finneran and Schlundt (2013); Kastelein et al. (2012a); Kastelein et al. (2012b); Kastelein et al. (2013a); Kastelein et al. (2019e); Kastelein et al. (2014a); Kastelein et al. (2014b); Kastelein et al. (2014c); Popov et al. (2014); Popov et al. (2013); Popov et al. (2011).
Under many circumstances TTS recovers linearly with the logarithm of time.	Finneran et al. (2010a, 2010b); Finneran and Schlundt (2013); Kastelein et al. (2012a); Kastelein et al. (2012b); Kastelein et al. (2013a); Kastelein et al. (2014a); Kastelein et al. (2014b); Kastelein et al. (2014c); Popov et al. (2014); Popov et al. (2013); Popov et al. (2011).

[1] In most acoustic impact assessments, the scenarios of interest involve shorter duration exposures than the marine mammal experimental data from which impact thresholds are derived; therefore, use of SEL tends to over-estimate the amount of TTS. Despite this, SEL continues to be used in many situations because it is relatively simple, more accurate than SPL alone, and lends itself easily to scenarios involving multiple exposures with different SPL and multiple sources.

Notes: PTS = permanent threshold shift; SEL = sound exposure level; SPL = sound pressure level; TTS = temporary threshold shift

The data from studies of hearing (i.e., composite audiograms, Figure D.4-2) and hearing loss in marine mammals were used to generate exposure functions – or predictions of hearing loss based on sound frequency, level, and type (continuous or impulsive) – for each hearing group (U.S. Department of the Navy, 2024a).

D.4.3.1 TTS Growth and Recovery

SEL is used to predict TTS in marine mammals based on available data (U.S. Department of the Navy, 2024a). These predictions likely hold true for shorter duration exposures, but for longer-duration exposures, SEL likely overestimates TTS (see Table D.4-2). In general, TTS increases with SEL in a non-linear fashion (Finneran, 2015). For lower SEL exposures, TTS will increase at a steady rate, but at higher SELs, TTS will either increase more rapidly or plateau (see U.S. Department of the Navy, 2024a).

Small amounts of TTS (a few dB) typically begin to recover immediately after the sound exposure and may fully recover in minutes, while larger amounts of TTS take longer to recover. Studies have also found substantial individual variation both in the amount of TTS produced by similar SELs (Kastelein et al., 2012a; Popov et al., 2013), and in recovery from similar TTS (Finneran, 2015; Kastelein et al., 2019e). For example, one harbor seal began recovering immediately after a 34 dB TTS, while a 45 dB TTS in another harbor seal only began recovering 4 - 24 hours after the exposure ended and complete recovery was observed after four days (Kastelein et al., 2020b). In general, recovery from TTS occurs linearly with the logarithm of time (Finneran, 2015).

Most of these findings are from studies that used continuous sound exposures, but intermittent, impulsive sound exposures have also been tested. The sound resulting from an explosive detonation is considered an impulsive sound and shares important qualities (i.e., short duration and fast rise time) with other impulsive sounds such as those produced by air guns, although explosive signals are characterized by sharper rises and higher peak pressures. There are no direct measurements of hearing loss in marine mammals due to exposure to explosive sources. Few studies using impulsive sounds have produced enough TTS to make predictions about hearing loss due to this source type (see U.S.

Department of the Navy, 2024a). In general, predictions of TTS based on SEL for this type of sound exposure is likely to overestimate TTS because some recovery from TTS may occur in the quiet periods between impulsive sounds – especially when the duty cycle is low. Peak SPL (unweighted) is also used to predict TTS due to impulsive sounds (Southall et al., 2007; Southall et al., 2019c; U.S. Department of the Navy, 2024a).

D.4.3.2 Self-Mitigation of Hearing Sensitivity

Several studies have shown that certain odontocete cetaceans (toothed whales) may learn to reduce their hearing sensitivity (presumably to protect their hearing) when warned of an impending intense sound exposure or the duty cycle is predictable (Finneran, 2018; Finneran et al., 2024; Nachtigall & Supin, 2013, 2014, 2015; Nachtigall et al., 2015; Nachtigall et al., 2016a, 2018; Nachtigall et al., 2016b). The effect has been demonstrated in the false killer whale (*Pseudorca crassidens*) (Nachtigall & Supin, 2013), bottlenose dolphin (*Tursiops truncatus*) (Finneran, 2018; Nachtigall & Supin, 2014, 2015; Nachtigall et al., 2016b), beluga (*Delphinapterus leucas*) (Nachtigall et al., 2015), and harbor porpoise (*Phocoena phocoena*) (Nachtigall et al., 2016a).

Based on these experimental measurements with captive odontocetes, it is possible that wild odontocetes would also suppress their hearing if they could anticipate an impending, intense sound, or during a prolonged exposure (even if unanticipated). Based on results from these conditioned hearing sensitivity experiments, odontocetes participating in some previous TTS experiments could have been protecting their hearing during exposures (Finneran, 2018; Finneran et al., 2024; Finneran et al., 2023). A better understanding of the mechanisms responsible for the observed hearing changes is needed for proper interpretation of some existing TTS data, particularly for TTS due to short-duration, unpredictable exposures.

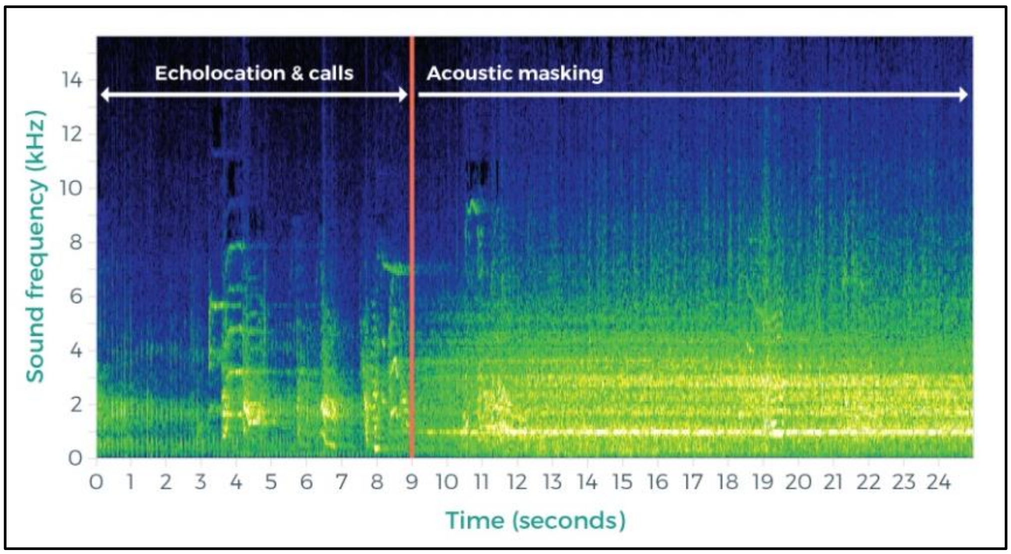
D.4.4 MASKING

This section provides an overview of masking in marine mammals, discusses the potential impacts of masking including communication space reduction and vocalization changes in response to noise, and reviews scientific literature specific to masking by anthropogenic sources. Detailed reviews and analysis of masking in marine mammals are provided by Clark et al. (2009), Erbe et al. (2016), and Branstetter and Sills (2022).

Most research on auditory masking measures the ability of the listener to detect a signal in noise. This is also called "energetic" masking. Energetic masking has been measured for pinnipeds (Sills et al., 2014, 2015; Southall et al., 2000, 2003), odontocetes (Au & Moore, 1990; Branstetter et al., 2021; Branstetter et al., 2017; Johnson et al., 1989; Kastelein & Wensveen, 2008; Lemonds et al., 2011; Thomas et al., 1990a), sirenians (Gaspard et al., 2012), and sea otters (Ghoul & Reichmuth, 2014b). These measurements allow predictions of masking if the spectral density of noise is known (Branstetter et al., 2017). Although energetic masking is typically estimated in controlled laboratory conditions using white noise, results can vary considerably depending on the noise type (Branstetter et al., 2013; Trickey et al., 2010). These fundamental measurements of the ability of marine mammals to detect different signal types under different masking noise conditions are useful for prediction of masking in real-world scenarios.

The frequency overlap between the signal and masker is perhaps the most important consideration when assessing the potential effect of noise. For example, higher frequency noise is more effective at masking higher frequency signals, (Au & Moore, 1990; Lemonds et al., 2011). Signal type (e.g., whistles, burst-pulse, echolocation clicks) and spectral characteristics (e.g., frequency modulation and/or harmonics) may further influence masked detection thresholds (Branstetter et al., 2016; Branstetter & Finneran, 2008; Branstetter et al., 2013; Cunningham et al., 2014). Figure D.4-3 shows an example of lower-frequency ship noise masking communication calls.

Much emphasis has been placed on signal detection in noise and, as a result, most masking studies and models have used masked signal detection thresholds. However, from a fitness perspective, signal detection does not equate to the ability to determine the sound source location and recognize "what" is producing the sound. Marine mammals use sound to recognize conspecifics, prey, predators, or other biologically significant sources. Masked recognition thresholds for whistle-like sounds, have been measured for bottlenose dolphins (Branstetter et al., 2016) and are approximately 4 dB above detection thresholds (signal detection masking) for the same signals. It should be noted that the term "threshold" typically refers to the listener's ability to detect or recognize a signal 50 percent of the time. For example, human speech communication, where only 50 percent of the words are recognized, would result in poor communication. Likewise, recognition of a conspecific call or the acoustic signature of a predator at only the 50 percent level could have severe impacts (Branstetter et al., 2016). Masking that may not result in a loss of signal detection, but results in loss of a signal's meaning is called informational masking.



Notes: Spectrogram showing killer whale communication calls and echolocation sounds in the first nine seconds, which are then masked by the passing of a ship. The ship's masking noise is predominant at 1.5 kHz and extends up to about 6 kHz. Some communication calls can be seen at 11 and 19 seconds. Echolocation calls (small vertical stripes) extend to much higher frequencies and are not masked as much as communication calls in this example. Figure from Kathy Heise and Tracy Saxby, Coastal Ocean Research Institute, https://oceanwatch.ca/bccoast/wp-content/uploads/sites/4/2018/10/OceanWatch-BC-Coast-underwater-noise.pdf

Figure D.4-3: Masking of Killer Whale Calls by a Passing Ship

Marine mammals use sound to recognize predators (Allen et al., 2014; Cummings & Thompson, 1971; Curé et al., 2015; Fish & Vania, 1971). Auditory recognition may be reduced in the presence of a masking noise, particularly if it occurs in the same frequency band. Therefore, the occurrence of masking may prevent marine mammals from responding appropriately to the acoustic cues produced by their predators. For example, studies have shown that for marine mammals that are preyed upon by killer whales, some recognition of predator cues might be missed if the killer whale vocalizations were masked (Curé et al., 2016; Curé et al., 2015; Deecke et al., 2002; Isojunno et al., 2016; Visser et al., 2016). This possibility depends on the duration of the masking and the likelihood of encountering a predator during the time that detection and recognition of predator cues are impeded. Relatively little data exists on informational masking in marine mammals despite its potential importance in models of how noise affects communication.

D.4.4.1 Masking Concepts

D.4.4.1.1 Release from Masking

Masking is less likely or is expected to be less impactful when the noise is intermittent, such as low-duty cycle sonars or impulsive noise, compared to when the noise is continuous, such as vessel noise, high-duty cycle sonar, or continuous active sonar. This is because for intermittent noise, the signal of interest can be detected during the quiet periods between noise events. This is often called “dip” or “gap” listening. The effect of masking on communication space is often modeled using constant-amplitude noise, whereas many anthropogenic sources contain gaps or fluctuations in the noise. Studies have shown that the signal duration, duty cycle, masker level, and fluctuations should be considered when modeling the effect of noise on signal detection (Branstetter & Finneran, 2008; Branstetter et al., 2013; Kastelein et al., 2021; Sills et al., 2017; Trickey et al., 2010).

Spatial release from masking (SRM) occurs when a noise and signal are separated in space, resulting in a reduction or elimination of masking (Holt & Schusterman, 2007; Popov et al., 2020). The relative position of sound sources can act as one of the most salient cues that allow the listener to segregate multiple sounds in a complex auditory scene. Many sounds are emitted from a directional source that is spatially separated from biologically relevant signals. Under such conditions, minimal masking will occur, and existing models of masking will overestimate the amount of actual masking. Marine mammals have excellent sound source localization capabilities (Branstetter & Mercado, 2006; Byl et al., 2019; Renaud & Popper, 1975) and directional hearing (Accomando et al., 2020; Au & Moore, 1984; Mooney et al., 2008; Popov & Supin, 2009) which likely combine to aid in separating auditory events and improving detection. Spatial release from masking has been empirically demonstrated using behavioral methods in a harbor seal a California sea lion, three harbor porpoises, and a bottlenose dolphin (Holt & Schusterman, 2007; Kastelein et al., 2021; Popov et al., 2020), where maximal spatial release from masking was 19, 12, 14.5, and 24 dB for each species respectively. The spatial positions of the receiver and noise source are often considered in terms of distance but the relative angles between the listening animal, the sound of interest (i.e., vocalization from other animals or prey echo from biosonar), and the noise source are also important to consider when estimating masking effects.

D.4.4.1.2 Communication Space Models of Masking

Communication space models estimate how the distance at which animals can communicate is reduced in noise. The term “communication space” typically means the distance an animal’s call can travel and feasibly be heard and interpreted by a listener. Since the range of available communication space varies widely with species and habitat, reduction in communication space is usually quantified as a percentage loss or a percentage of space available during increased anthropogenic and ambient noise.

Models typically include the source level and frequency characteristics of both the animal of interest’s vocalization and the noise, and the spatial relationship between the noise source and the calling animal and/or the listener. The listener (i.e., receiver) is considered in the best available communication space models, which use the listener’s hearing characteristics when data are available. Models vary in their implementation of propagation modeling – or how the sound (signal and noise) levels are reduced with distance. Some use simple spherical spreading loss while others employ more sophisticated location-specific estimates, and these choices are related both to the specific research question and the availability of empirical data or existing propagation models.

Clark et al. (2009) estimated masking effects on communication signals for three species of calling mysticete whales (LF cetaceans), including calculating the cumulative impact of multiple noise sources. For example, the model estimates that a right whale's optimal communication space (around 20 km) is decreased by as much as 84 percent when two commercial ships pass by. When one ship passed, communication space for singing fin and humpback whales briefly decreased by approximately 20 and 8 percent respectively when the ship passed close to the whales. For the same ship passage, right whale communication space was reduced by approximately 77 percent. These differences were due to the call repetition rate, source level, and call frequency differences between species. Notably, the right whale calls had a much lower repetition rate in comparison to humpback and fin whale calls. In another study, Hatch et al. (2012) found that North Atlantic right whale communication space was reduced by 67 percent during exposure to vessel noise.

An experiment in a shallow water environment (less than 50 m depth) investigating humpback whale sounds (vocalizations and surface-generated sounds) determined that, in typical ambient (wind) noise, their communication range extends to approximately 2 - 4 km (Dunlop, 2018). Considering this baseline space restricted by ambient noise, Dunlop (2019) used vocalization and whale interactions to show a reduction in humpback whale communication space in vessel noise. This study concluded that the physical presence of the vessel could possibly explain changes in social behavior. This example illustrates the overall concept that changes in behavior observed in the field, including vocalization, often cannot be ascribed solely to masking noise, but also to the physical presence of the noise source.

Results from additional scientific studies on communication space, primarily from vessel noise are listed in Table D.4-3.

Table D.4-3: Communication Space Models of Masking in Marine Mammals

Species	*Location*	*Anthropogenic Noise Source*	*Communication Space Reduction*	*Call Type*	*Study*
North Atlantic right whale (*Eubalaena glacialis*)	Stellwagen Bank National Sanctuary, USA	Passing vessels	77% (single vessel) 84% (two vessels)	71 – 224 Hz contact call	Clark et al. (2009)
		AIS[1], fishing, and whale-watching vessels	5%	36 – 891 Hz "gunshot" call	Cholewiak et al. (2018)
Humpback whale (*Megaptera novaeangliae*)	Stellwagen Bank National Sanctuary, USA	Single vessel passing	8%	224 – 708 Hz song	Clark et al. (2009)
		AIS, fishing, and whale-watching vessels	80 – 99%[2]	36 – 355 Hz song and social sounds	Cholewiak et al. (2018)
	Glacier Bay National Park, USA	AIS vessel traffic, summer season	13 – 28% (song) 18 – 51% (calls)	224 – 708 Hz song, 50 – 700 Hz "whup" calls	Gabriele et al. (2018)[2]
	Peregian Beach, Australia	Vessel-dominated noise	25 – 50%	Low-frequency calls (≤ 126 Hz min., ≤ 159 Hz center frequency) and high-frequency calls (> 159 Hz center frequency)	Dunlop (2019)

Species	***Location***	***Anthropogenic Noise Source***	***Communication Space Reduction***	***Call Type***	***Study***
	Colombian Pacific	Vessel (whale-watching/ecotour)	63%	350 Hz peak frequency	Rey-Baquero et al. (2021)
Fin whale (*Balaenoptera physalus*)	Stellwagen Bank National Sanctuary, USA	Single vessel passing	20%	18 -28 Hz song	Clark et al. (2009)
		AIS[1], fishing, and whale-watching vessels	80 – 99%[2]	18 – 22 Hz song	Cholewiak et al. (2018)
Bryde's whale (*Balaenoptera edeni*)	Hauraki Gulf, New Zealand	AIS[1] vessels	≤ 87%	23.5 – 207.8 Hz calls	Putland et al. (2018)
Minke whale (*Balaenoptera acutorostrata*)	Stellwagen Bank National Sanctuary, USA	AIS[1], fishing, and whale-watching vessels	≥ 80%	56 – 355 Hz pulse trains	Cholewiak et al. (2018)
Killer whale (*Orcinus orca*)	Haro Strait, USA	Vessels	62 – 97%	1.5 – 3.5 kHz	Williams et al. (2014a)
	Salish sea	Vessels and wind	50 – 90%	1 – 50 kHz	Burnham et al. (2023)
Beluga whale (*Delphinapterus leucas*)	Saguenay - St. Lawrence Marine Park, Canada	Car ferries, whale watching vessels, small vessels	70 – 85%	2.5 kHz center frequency	Gervaise et al. (2012)
	St. Lawrence Estuary, Canada	Vessels	53 – 57%	Adult, sub-adult, and calf communication calls	Vergara et al. (2021)
Bottlenose dolphin (*Tursiops* sp.)	Tenerife, Canary Islands, Spain	Vessels	26%	4 – 10 kHz whistles	Jensen et al. (2009)
Short-finned pilot whale (*Globicephala macrorhynchus*)			58%	2 – 12.5 kHz tonal sounds	
Harbor seal (*Phoca vitulina*)	Glacier Bay National Park, USA	AIS[1] vessel traffic, summer season	32 – 61%	4 – 500 Hz "roar"	Gabriele et al. (2018)

[1]AIS = Automatic Identification System, certain types of vessels are outfitted with transponders that provide position information.
[2] This communication space reduction value is based on increase in anthropogenic noise and ambient (natural) background noise increases combined
Notes: % = percent; < = less than; > = greater than; ≤ = less than or equal to; ≥ = greater than or equal to; AIS = Automatic Identification System; Hz = Hertz

These studies demonstrate that anthropogenic sounds – especially broadband vessel noise – can reduce the communication space available to marine mammals. Existing models tend to simplify the noise characteristics such as how the sound propagates away from the noise source, and the auditory capabilities of the listener (e.g., do not consider directional hearing). Additionally, as pointed out by Branstetter and Sills (2022), many of these models are based on an assumed signal detection and recognition threshold – usually a 10 dB signal-to-noise ratio (Clark et al., 2009).

D.4.4.1.3 Noise-Induced Vocal Modifications

Masking noise can result in vocal modifications or other acoustic signaling behaviors that might reduce or compensate for the overall effect of masking. These noise-induced vocal modifications (NIVM) include increasing the source level (Lombard effect), modifying the frequency, increasing the repetition rate of vocalizations, or ceasing to vocalize in the presence of increased noise (Hotchkin & Parks, 2013). With increased natural background (ambient) noise levels, a switch from vocal communication to physical, surface-generated sounds such as pectoral fin slapping or breaching was has been observed in mysticete whales (Dunlop et al., 2010).

Vocalization changes have been reported from exposure to anthropogenic noise sources such as sonar, vessel noise, and seismic surveying (Gordon et al., 2003; Holt et al., 2011; Holt et al., 2008; Lesage et al., 1999; McDonald et al., 2009; Nowacek et al., 2007; Rolland et al., 2012) as well as changes in the natural acoustic environment (Brumm & Slabbekoorn, 2005). It is often difficult to discriminate NIVM from potential effects of context, measurement tools, and analysis methods. For example, vocalizations may be masked from the recorder, or confounded by other behavioral responses of the marine mammal such as moving away from the noise and recorder or increasing dive duration (Castellote et al., 2012; Cerchio et al., 2014). The ability to observe NIVM might also depend on the methods used to quantify baseline behavior and timescale over which recordings are analyzed (Casey et al., 2024). Table D.4-4 details some examples of the best available scientific observations of noise-induced vocal modifications in marine mammals due to anthropogenic and ambient noise.

Table D.4-4: Examples of Noise-Induced Vocal Modifications in Marine Mammals

Species	***Study***	***Noise source***	***Vocalization Change***			
			Rate	***Duration***	***Frequency***	***Amplitude***
Blue whale (*Balaenoptera musculus*)	Di Lorio and Clark (2010)	Seismic survey (sparker pulses, average received SELs of 131 dB re 1 $\mu Pa^2 s$)	↑			
	Shabangu et al. (2022)	Vessel (10 – 500 Hz)	↑			
		Wind (1 – 4 kHz)	↓[2] masked			
North Atlantic right whale (*Eubalaena glacialis*)	Parks et al. (2011); Parks et al. (2009).	Ambient (20 Hz – 8 kHz)	↓		↑[1]	↑ Lombard
Humpback whale (*Megaptera novaeangliae*)	Girola et al. (2023)	Wind				↑ Lombard, 0.5 dB for every 1 dB increase
		Vessels				NC
	Shabangu et al. (2022)	Wind				↑ Lombard
	Laute et al. (2022)	Vessels	↓			
	Dunlop et al. (2014)	Ambient wind noise				↑

Species	Study	Noise source	Vocalization Change			
			Rate	Duration	Frequency	Amplitude
						Lombard, 0.9 dB for every 1 dB noise increase
	Dunlop (2016)	Vessels		NC	NC	↓ Masked[2]
	Fournet et al. (2018)	Vessels and ambient	↓ 9% for every 1 dB noise increase			↑ Lombard, 0.8 dB for every 1 dB noise increase
	Fristrup et al. (2003); Miller et al. (2000)	Low-frequency active sonar		↑ overall song length		
Bowhead whale (*Balaena mysticetus*)	Blackwell et al. (2015); Blackwell et al. (2017)	Seismic survey (air gun pulses) and large-scale drilling operation (tonal drilling, vessels)	↑ Noise levels < 127 dB ↓ Noise levels > 127 dB X Noise level 170 dB			
Beluga (*Delphinapterus leucas*)	Lesage et al. (1999)	Small vessels	↓ overall ↑ certain call types		↑ bandwidth	
Beluga (*Delphinapterus leucas,* St. Lawrence Estuary)	Scheifele et al. (2005)	Vessels				↑ Lombard
Killer whale (*Orcinus orca*)	Foote et al. (2004)	Vessels	NC	↑		
Killer whale (*Orcinus orca,* Southern Resident)	Wieland et al. (2010)	Vessels		↑14 call types ↓ 2 call types		
	Holt et al. (2011); (2008)	Vessels				↑ Lombard

Species	Study	Noise source	Vocalization Change			
			Rate	Duration	Frequency	Amplitude
Bottlenose dolphin (*Tursiops sp.*)	Buckstaff (2004)	Vessels	↑ Vessel approach	NC	NC	
	Luís et al. (2014)	Vessels	↓			
	Gospić and Picciulin (2016)	Vessels (low-frequency noise)			↑	
	Antichi et al. (2022)	Vessels (single small vessel passages)			Coastal dolphins ↑, Oceanic dolphins ↓ (after approach)	
Delphinids (multiple species)	Papale et al. (2015)	Anthropogenic and ambient noise			↑ min/max frequency	
Dugong (*Dugong dugon*)	Ando-Mizobata et al. (2014)	Vessels (within 400 m)	NC	↑	↑ bandwidth	
Harbor seal (*Phoca vitulina*, pups, 1 – 3 weeks old)	Torres Borda et al. (2021)	Broadband recorded ambient noise playback	NC	NC	↓ fundamental frequency	↑ Lombard in three of eight seals
Bearded seal (*Erignathus barbatus*)	Fournet et al. (2021)	Ambient (below 900 Hz)				↑ Lombard

[1] Call frequency and Lombard effect are often interrelated.
[2] In many studies, decreases in call amplitude or detections (calling rates) can result from masking of the recording hydrophone (receiver) rather than a change in the animal's vocal behavior.
Notes: ↑ = increase; ↓ = decrease; % = percent; < = less than; > = greater than; μPa^2s = micropascal squared seconds; dB = decibel; Hz = Hertz; kHz = kilohertz; NC = no change; SEL = sound exposure level; X = ceased calling

In some scenarios, depending on the capability of the individual animal to adjust the frequency and/or source levels of their calls and the characteristics of anthropogenic noise, vocal modifications might not compensate for masking. For example, Fournet et al. (2021) showed that estimated source levels of seal calls increased with ambient noise up to approximately 100-105 dB rms, above which no further Lombard effect was observed. This suggests that masking of bearded seal mating calls may occur in the presence of noise that exceeds 100 dB.

Vocal and other behavioral changes in response to masking noise might have fitness consequences, such as those that could result from an increase in metabolic rates and oxygen consumption, as was found for bottlenose dolphins when increasing their call amplitude (Holt et al., 2015). Some species might avoid changing the source levels or frequencies of their vocalizations to avoid predation or suffer increased risks of predation due to these vocal modifications. For example, beaked whales that modify their vocalizations might compromise otherwise cryptic foraging strategies which function to avoid predation by killer whales (Aguilar de Soto et al., 2006; Brumm & Slabbekoorn, 2005).

D.4.4.2 Masking by Anthropogenic Noise Sources

This section summarizes the predicted effects of masking by each type of anthropogenic noise source on marine mammals based on the information presented above. Examples of studies specific to vessel noise, sonar, and impulsive sounds are also discussed. The most important considerations for potential masking are the source level, frequency, duty cycle, and range (distance between masker and listening or calling animal).

D.4.4.2.1 Masking by Vessel Noise

Masking of marine mammal vocalizations is most likely to occur in the presence of broadband, relatively continuous noise sources such as vessels. This type of noise overlaps in frequency with many marine mammal sounds and can effectively reduce their communication space. Both signal detection and informational masking are likely to occur in the presence of vessel noise (Erbe et al., 2016). Models of communication space reduction (Table D.4-3) have predicted substantial decreases in communication space for a variety of species. When there is persistent vessel noise such as in a busy harbor, this effect is likely to be pervasive in nearby habitats as compared to intermittent when vessels pass through a habitat with lower ambient noise levels.

It is also possible that high source level vessel noise could mask marine mammal echolocation sounds. Hermannsen et al. (2014) estimated that broadband vessel noise could extend up to 160 kHz at ranges from 60 to 1,200 m, and that the higher frequency portion of that noise might mask harbor porpoise clicks. However, masking might not occur in practice, since harbor porpoises may avoid vessels and therefore may not be close enough to have their clicks masked (Dyndo et al., 2015; Polacheck & Thorpe, 1990; Sairanen, 2014). Liu et al. (2017) found that broadband shipping noise could cause masking of humpback dolphin whistles within 1.5–3 km, and masking of echolocation clicks within 0.5–1.5 km. Williams et al. (2014a) found that killer whale echolocation clicks (18 – 60 kHz) in Haro Strait were not masked by vessel noise over a 2 km distance. Gervaise et al. (2012) showed that the echolocation frequency range of belugas in the Saguenay-St. Lawrence Marine Park was masked by car ferry noise.

Overall, vessel noise has a substantial probability of masking marine mammal communication sounds and can also mask echolocation sounds in some cases. However, many studies of vessel noise masking do not consider spatial release from masking [e.g., (Brewer et al., 2023)], which is likely to reduce the effect of masking if the vessel is spatially separated from the signal of interest; this is especially relevant for situations where avoidance behavior is also exhibited. The overall potential effects of masking by vessel noise are (1) a reduction in the ability of marine mammals to communicate, detect, or interpret biologically relevant sounds, (2) costs associated with noise-induced vocal modifications such as the Lombard effect, or (3) costs associated with other behavioral responses to masking noise or the physical presence of vessels (see Behavioral Reactions D.4.5).

D.4.4.2.2 Masking by Sonar

Because military sonars typically have low duty cycles, relatively short duration, and narrow bandwidth that does not overlap with vocalizations for most marine mammal species, masking would be limited as compared to continuous sources (e.g., vessel noise). Dolphin whistles and mid-frequency active sonar are similar in frequency, so masking is possible but less likely due to the low-duty cycle and short durations of most sonars and the probability that dip listening would occur. For similar reasons, masking caused by low-frequency active sonar may be limited where it overlaps in frequency with some mysticete vocalizations (e.g., minke and humpback whales) (Fristrup et al., 2003; Miller et al., 2000).

High-duty cycle or continuous active sonars have the potential to mask marine mammal vocalizations. These sonars transmit more frequently than intermittent sonars, but typically at lower source levels. While the lower source levels limit the range of impact compared to other systems, animals close to the sonar source are likely to experience masking on a much longer time scale than those exposed to intermittent sonars. Continuous noise at the same frequency of communicative vocalizations may cause disruptions to communication, social interactions, and acoustically mediated cooperative behaviors (Sørensen et al., 2023) such as foraging and mating. Similarly, because the high-duty cycle or continuous active sonar are mid-frequency, there is the potential for the sonar signals to mask important environmental cues like predator vocalizations (e.g., killer whales), possibly affecting prey (including other marine mammals). Spatial release from masking may occur with higher duty cycle or continuous active sonars.

von Benda-Beckmann et al. (2021) modeled the effect of pulsed and continuous 1-2 kHz active sonar on sperm whale echolocation clicks and found that the presence of upper harmonics in the sonar signal increased masking of clicks produced in the search phase of foraging compared to buzz clicks produced during prey capture. Different levels of sonar caused intermittent to continuous masking (120 to 160 dB re 1 μPa^2, respectively), but varied based on click level, whale orientation, and prey target strength. Continuous active sonar resulted in a greater percentage of time that echolocation clicks were masked compared to pulsed active sonar. This means that sonar sounds could reduce the ability of sperm whales to find prey under certain conditions. However, echoes from prey are most likely spatially separated from the sonar source, and so spatial release from masking would be expected.

Overall, sonar has the potential to mask marine mammal communication sounds and echolocation clicks. Continuous active sonar is more likely to mask vocalizations than intermittent sonar, and in general, sonar is less likely than vessel noise to have masking effects on sounds that are biologically relevant to marine mammals.

D.4.4.2.3 Masking by Impulsive Sound Sources

Impulsive sound sources, including explosions, are intense and short in duration (see D.1.1.5). Since impulsive noise is intermittent, the length of the gap between sounds (duty-cycle) and received level are pertinent when considering the potential for masking. Impulsive sounds with lower duty cycles or lower received levels are less likely to result in masking than higher duty cycles or received levels. There are no direct observations of masking in marine mammals due to exposure to explosive sources. Potential masking from explosive sounds or weapon noise is likely similar to masking studied for other impulsive sounds, such as air guns or pile-driving.

Masking of mysticete calls could occur due to the overlap between their low-frequency vocalizations and the dominant frequencies of impulsive sources (Castellote et al., 2012; Nieukirk et al., 2012). For example, blue whale feeding/social calls increased when seismic exploration was underway (Di Lorio & Clark, 2010), indicative of a possible compensatory response to masking effects of the increased noise level. However, mysticetes that call at higher rates are less likely to be masked by impulsive noise with lower duty cycles (Clark et al., 2009) because of the decreased likelihood that the noise would overlap with the calls, and because of dip listening. Field observations of masking effects such as vocal modifications are difficult to interpret because when recordings indicate that call rates decline, this could be caused by (1) animals calling less frequently (actual noise-induced vocal modifications), (2) the calls being masked from the recording hydrophone due to the noise (e.g., animals are not calling less frequently but are being detected less frequently), or (3) the animals moving away from the noise, or any combination of these causes (Blackwell et al., 2013; Cerchio et al., 2014).

Masking of pinniped communication sounds at 100 Hz center frequency is possible when vocalizations occur at the same time as an air gun pulse (Sills et al., 2017). This might result in some percentage of vocalizations being masked if an activity such as a seismic survey is being conducted in the vicinity, even when the sender and receiver are near one another. Release from masking due to "dip listening" is likely in this scenario.

While a masking effect of impulsive noise can depend on the received level (Blackwell et al., 2015) and other characteristics of the noise, the vocal response of the affected animal to masking noise is an equally important consideration for inferring overall impacts to an animal. As illustrated in Table D.4-4, it is possible that the receiver would increase the rate and/or level of calls to compensate for masking; or, conversely, cease calling.

In general, impulsive noise has the potential to mask sounds that are biologically important for marine mammals, reducing communication space or resulting in noise-induced vocal modifications that might impact marine mammals. Masking by close-range impulsive sound sources is most likely to impact marine mammal communication.

D.4.5 Behavioral Reactions

Any stimulus in the environment can cause marine mammals to react, including noise from anthropogenic sources such as vessels, sonar, or aircraft, as well as the physical presence of a vessel or aircraft. Marine mammal responses to anthropogenic sound were reviewed by Richardson et al. (1995b). Other reviews (Nowacek et al., 2007; Southall et al., 2007) addressed studies conducted since 1995 and focused on observations where the received sound level was known or could be estimated, and discussed the role of context. Southall et al. (2007) synthesized data from many past behavioral studies and observations to determine the likelihood of behavioral reactions at specific sound levels, and Southall et al. (2016) reviewed the range of experimental field studies that have been conducted to measure behavioral responses of cetaceans to sonar.

Considerable variability has been observed in marine mammal responses to sound. Methods have been developed and refined to categorize and assess the severity of acute responses, considering impacts to individuals that may consequently impact populations (Southall et al., 2007; Southall et al., 2021). These severity scales assess immediate discrete responses in relation to behaviors affecting vital rates, including survival, reproduction, and foraging. Using these scales, a behavioral response by a wild (non-captive) marine mammal may range from low severity (e.g., detectable interruptions in foraging, diving, or courtship behavior) to moderate severity (e.g., avoidance, sustained foraging reduction) to high severity (e.g., separation of mother-offspring, prolonged displacement from foraging habitat, repeated breeding disruption leading to reduced reproductive success). Captive animal behavior studies allow for controlled, repeated exposures with very precise measures, but captive marine mammals may have training and motivational contexts that make their responses difficult to compare to free-ranging, non-captive animals (Southall et al., 2021). Therefore, behavioral severity scales developed for captive marine mammals consider other factors such as trained behaviors, use of rewards, and habituation.

While in general, the louder the sound source, the more intense the behavioral response, it was clear that the proximity of a sound source and the animal's experience, motivation, and conditioning were also critical factors influencing the response (Southall et al., 2007; Southall et al., 2016). Ellison et al. (2011) submit that "exposure context" greatly influences the type of behavioral response exhibited by an animal and outlined an approach to assessing the effects of sound on marine mammals that considers not just the received level of sound, but also in what activity the animal is engaged, the nature and novelty of the sound (i.e., is this a new sound from the animal's perspective), and the distance between the sound source and the animal. Other variables and contextual factors that may affect the probability and magnitude of a behavioral response include subject-specific factors (e.g., age, sex, presence of a calf, and group size and composition), characteristics of the sound (frequency, duration, similarity to predator sounds, and whether it is continuous or intermittent); whether the sound is approaching or moving away; the presence of predators, prey, or conspecifics; and navigational constraints on the animal (Ellison et al., 2011; Southall et al., 2021; Wartzok et al., 2003).

Extensive research programs have and are investigating the responses of free-ranging marine mammals to anthropogenic sounds, including actual and simulated tactical sonars both on and off military ranges (Southall et al., 2016). These behavioral response studies include controlled exposure studies, in which detailed acoustic dose and behavioral data are obtained from tags on focal animals, as well as data obtained from longer-term tags and passive acoustic monitoring during opportunistic exposures to actual sonar on naval training and testing ocean ranges with bottom-mounted hydrophones (Harris et al., 2018). Table D.4-5 provides an overview of current and past efforts as background to the findings presented in the taxa-specific sections below.

Table D.4-5: Major Non-Captive Behavioral Response Studies

Project/ Location	*Focal Species*	*Sound source*	*Studies*
Opportunistic Studies on Navy instrumented Ranges			
AUTEC, Bahamas	Blainville's beaked whale	Navy hull-mounted sonar	Joyce et al. (2019); McCarthy et al. (2011); Moretti et al. (2014); Tyack et al. (2011)
SOCAL Anti-Submarine Warfare Range	Goose-beaked whale	Navy hull-mounted and dipping sonar	Falcone et al. (2017)
Pacific Missile Range Facility, Hawaii	Minke whale Humpback whale Blainville's beaked whale	Navy hull-mounted sonar	Durbach et al. (2021); Harris et al. (2019b); Henderson et al. (2019); Henderson et al. (2016); Manzano-Roth et al. (2016); Martin et al. (2015)
BRS with Controlled Exposure Experiments			
AUTEC-BRS (Bahamas)	Blainville's beaked whales	Simulated tactical sonar	Tyack et al. (2011)
3S1[1] (Norway)	Killer whale Long-finned pilot whale Sperm whale	Simulated tactical sonar (1 – 2 kHz or 6 – 7 kHz, intermittent)	Antunes et al. (2014); Curé et al. (2016); Isojunno et al. (2016); Isojunno et al. (2017); Miller (2012); Miller et al. (2014); Sivle et al. (2012b); Visser et al. (2016)
3S2[1] (Norway)	Humpback whale Minke whale Northern bottlenose whale	Simulated tactical sonar (1 – 2 kHz or 6 – 7 kHz, intermittent)	Curé et al. (2021); Kvadsheim et al. (2017); Miller et al. (2015); Sivle et al. (2015b); Sivle et al. (2016b); Wensveen et al. (2019); Wensveen et al. (2017)
3S3[1] (Norway)	Sperm whale Long-finned pilot whale	Simulated tactical sonar (1 – 2 kHz continuous and intermittent)	Curé et al. (2021); Isojunno et al. (2021); Isojunno et al. (2020)
SOCAL BRS	Blue whale Fin whale Minke whale Baird's beaked whale Goose-beaked whale Risso's dolphin	Simulated tactical sonar (3.5 – 4 kHz intermittent)	DeRuiter et al. (2013b); Friedlaender et al. (2016); Goldbogen et al. (2013); Kvadsheim et al. (2017); Southall et al. (2019b); Stimpert et al. (2014); Southall et al. (2023)
Atlantic BRS[2]	Goose-beaked whale Short-finned pilot whale	Simulated tactical sonar (3 – 4 kHz,	

Project/ Location	Focal Species	Sound source	Studies
		intermittent) and Navy hull-mounted sonar	

[1] 3S = Sea mammals and Sonar Safety

[2] This is the most recent BRS efforts; thus, peer-reviewed publications of findings are not yet available.

Notes: AUTEC = Atlantic Undersea Test and Evaluation Center; BRS = Behavioral Response Studies; kHz = kilohertz; SOCAL = Southern California

For most species, little or no data exist on behavioral responses to any sound source. For the below synthesis of best available science on marine mammal behavioral responses, all species have been grouped into broad taxonomic groups from which general response information can be inferred.

D.4.5.1 Behavioral Reactions of Mysticetes

D.4.5.1.1 Sonar and Other Transducers

The responses of mysticetes to sonar and other duty-cycled tonal sounds depend on the characteristics of the signal, behavioral state of the animal, sensitivity and previous experience of an individual, and other contextual factors including distance of the source, movement of the source, physical presence of vessels, time of year, and geographic location (Goldbogen et al., 2013; Harris et al., 2019a; Harris et al., 2015; Martin et al., 2015; Sivle et al., 2015b). Behavioral response studies have been conducted over a variety of contextual and behavioral states, helping to identify which factors, beyond the received level of the sound, may lead to a response. Observed reactions during behavioral response studies have not been consistent across individuals based on received sound levels alone, and likely were the result of complex interactions between these contextual factors.

In the SOCAL BRS, tagged surface feeding blue whales did not show a change in behavior in response to mid-frequency simulated and incidental Navy sonar sources with received levels between 90 and 179 dB re 1 µPa, but deep feeding and non-feeding whales showed temporary reactions including cessation of feeding, reduced initiation of deep foraging dives, generalized avoidance responses, and changes to dive behavior. The behavioral responses were generally brief, of low to moderate severity, and highly dependent on exposure context (behavioral state, source-to-whale horizontal range, and prey availability), with a return to baseline behavior shortly after the end of the exposure (DeRuiter et al., 2017; Goldbogen et al., 2013; Southall et al., 2019c). When the prey field (krill) was mapped and used as a covariate in models looking for a response in the 2011-2013 SOCAL BRS data set, the response in deep-feeding blue whales was even more apparent, reinforcing the need for contextual variables, such as feeding state, to be included when assessing behavioral responses (Friedlaender et al., 2016). The probability of a moderate behavioral response increased when the range to source was closer for these foraging blue whales, although there was a high degree of uncertainty in that relationship (Southall et al., 2019b). None of the tagged fin whales in the SOCAL BRS demonstrated more than a brief or minor response regardless of their behavioral state (Harris et al., 2019a). The fin whales were exposed to both mid-frequency simulated sonar and pseudorandom noise of similar frequency, duration, and source level. They were less sensitive to disturbance than blue whales, with no significant differences in response between behavioral states or signal types. The authors rated responses as low-to-moderate severity with no negative impact to foraging success (Southall et al., 2023).

Similarly, humpback whale behavioral responses to sonar have been influenced by foraging state. During sonar exposure of tagged whales in the 3S2 study, the rates of foraging lunges generally decreased, but responses varied across individuals (e.g., ceasing or starting to forage); most of the non-foraging humpback whales did not respond to any approaches at all (Sivle et al., 2016b). For foraging whales, lunges decreased (although not significantly) during a no-sonar control vessel approach prior to the sonar exposure, and lunges decreased less during a second sonar approach than during the initial approach. There was also variability in humpback avoidance responses. Some tagged whales in the 3S2 study avoided the sonar vessel only during the first or second exposure, and only one whale avoided both (Sivle et al., 2016b). This suggests that there may have been responses to the vessel or habituation to the sonar and vessel after repeated approaches. Almost half of the animals with avoidance responses were foraging before the exposure; the non-feeding whales that avoided responded at a slightly lower received level and greater distance than those that were feeding (Wensveen et al., 2017). When responses did occur the animals quickly returned to their previous behavior after the sound exposure ended (Sivle et al., 2015b). Changes in foraging duration during mammal-eating killer whale playbacks and mid-frequency sonar were positively correlated across multiple species in the 3S Norwegian studies, including humpback whales, suggesting that tolerance of predation risk may play a role in sensitivity to sonar disturbance (Miller et al., 2022), with the humpback whales responding more severely to the killer whale vocalization playbacks than they did to the sonar playbacks (Curé et al., 2015; Sivle et al., 2015b).

The most severe baleen whale response in any behavioral response study was observed in a minke whale in the 3S2 study, which responded to simulated naval sonar at a received level of 146 dB re 1 µPa by strongly avoiding the sound source (Kvadsheim et al., 2017; Sivle et al., 2015b). Although the minke whale increased its swim speed, directional movement, and respiration rate, none of these were greater than rates observed in baseline behavior, and its dive behavior remained similar to baseline dives. A minke whale tagged in the SOCAL behavioral response study also responded by increasing its directional movement, but maintained its speed and dive patterns, and so did not demonstrate as strong of a response (Kvadsheim et al., 2017). In addition, the 3S2 minke whale demonstrated some of the same avoidance behavior during the controlled ship approach with no sonar, indicating at least some of the response was to the vessel (Kvadsheim et al., 2017).

In addition to behavioral response studies, responses by humpback and minke whales to actual training activities on Navy ranges have been monitored. Several humpback whales have been observed during aerial or visual surveys during Navy training events involving sonar; no avoidance or other behavioral responses were ever noted, even when the whales were observed within 5 km of a vessel with active sonar and maximum received levels were estimated to be between 135 and 161 dB re 1 µPa (Mobley, 2011; Mobley & Milette, 2010; Mobley & Pacini, 2012; Mobley et al., 2012; Smultea et al., 2009). In fact, one group of humpback whales approached a vessel with active sonar so closely that the sonar was shut down and the vessel slowed; the animals continued approaching and swam under the bow of the vessel (U.S. Department of the Navy, 2011a). Another group of humpback whales continued heading towards a vessel with active sonar as the vessel was moving away for almost 30 minutes, with an estimated median received level of 143 dB re 1 µPa. This group was observed producing surface active behaviors such as pec slaps, tail slaps, and breaches; however, these are very common behaviors in competitive pods during the breeding season and were not considered to have occurred in response to the sonar (Mobley et al., 2012).

Monitoring at the Pacific Missile Range Facility off Kaua'i has provided data on humpback and minke responses to naval anti-submarine warfare sonars in actual training conditions. Henderson et al. (2019) examined the dive and movement behavior of tagged humpback whales, including whales incidentally exposed to sonar during Navy training activities. Tracking data showed that individual humpbacks spent limited time, no more than a few days, in the vicinity of Kaua'i, even without sonar exposure. Potential behavioral responses to sonar exposure were limited and may have been influenced by engagement in breeding and social behaviors. Martin et al. (2015) found that the density of calling minke whales was reduced during periods of Navy training involving sonar relative to the periods before training and increased again in the days after training was completed. The responses of individual whales could not be assessed, so in this case it is unknown whether the decrease in calling animals indicated that the animals left the range or simply ceased calling. Harris et al. (2019b) utilized acoustically generated minke whale tracks to statistically demonstrate changes in the spatial distribution of minke whale acoustic presence before, during, and after surface ship mid-frequency active sonar training. The spatial distribution of probability of acoustic presence was different in the “during” phase compared to the “before” phase, and the probability of presence at the center of ship activity during mid-frequency active sonar training was close to zero for both years. The “after” phases for both years retained lower probabilities of presence suggesting the return to baseline conditions may take more than five days. The results show a clear spatial redistribution of calling minke whales during surface ship mid-frequency active sonar training, however a limitation of passive acoustic monitoring is that one cannot conclude if the whales moved away, went silent, or a combination of the two. Building on this work, Durbach et al. (2021) used the same data and determined that individual minke whales tended to be in either a fast or slow movement behavior state while on the range, where whales tended to be in the slow state in baseline or before periods but transitioned into the fast state with more directed movement during sonar exposures. They also moved away from the area of sonar activity on the range, either to the north or east depending on where the activity was located; this explains the spatial redistribution found by Harris et al. (2019b). Minke whales were also more likely to stop calling when in the fast state, regardless of sonar activity, or when in the slow state during sonar activity (Durbach et al., 2021). Similarly, minke whale detections made using Marine Acoustic Recording Instruments off Jacksonville, Florida, were reduced or ceased altogether during periods of sonar use (Norris et al., 2012; U.S. Department of the Navy, 2013), especially with an increased ping rate (Charif et al., 2015).

Other opportunistic passive acoustic based studies have also detected behavioral responses of blue and humpback whales to sonar, although definitive conclusions are harder to draw. Blue whales exposed to mid-frequency sonar in the Southern California Bight were less likely to produce low-frequency calls usually associated with feeding behavior, beginning at received levels of 110–120 dB re 1 µPa (Melcón et al., 2012); however, without visual observations it is unknown whether there was another factor that contributed to the reduction in foraging calls, such as the presence of conspecifics. In another example, Risch et al. (2012, 2014) determined that humpback whale song produced in the Stellwagen Bank National Marine Sanctuary was reduced while an Ocean Acoustic Waveguide Remote Sensing experiment was occurring 200 km away. They concluded that the reduced song was a result of the Ocean Acoustic Waveguide Remote Sensing. However, Gong et al. (2014) analyzed the same data set while also looking at the presence of herring in the region, and found that the singing humpbacks were actually located on nearby Georges Bank and not on Stellwagen, and that the song rate in their data did not change in response to Ocean Acoustic Waveguide Remote Sensing, but could be explained by natural causes.

Baleen whales have also been exposed to lower frequency sonars, with the hypothesis that they may react more strongly to lower frequency sounds that overlap with their vocalization range. One series of studies was undertaken in 1997–1998 pursuant to the Navy’s Low Frequency Sound Scientific Research Program. The frequency bands of the low-frequency sonars used were between 100 and 500 Hz, with received levels between 115 and 150 dB re 1 µPa, and the source was always stationary. Fin and blue whales were targeted on foraging grounds, singing humpback whales were exposed on breeding grounds, and gray whales were exposed during migratory behavior. These studies found only short-term responses to low-frequency sound by some fin and humpback whales, including changes in vocal activity and avoidance of the source vessel, while other fin, humpback, and blue whales did not respond at all. When the source was in the path of migrating gray whales they changed course up to 2 km to avoid the sound, but when the source was outside their path, little response was observed although received levels were similar (Clark & Fristrup, 2001; Croll et al., 2001; Fristrup et al., 2003; Miller et al., 2000; Nowacek et al., 2007). Low-frequency signals of the Acoustic Thermometry of Ocean Climate sound source were also not found to affect dive times of humpback whales in Hawaiian waters (Frankel & Clark, 2000).

In contrast to actual or simulated naval sonar, some studies have examined responses to underwater tones or alarms intended to serve as deterrents (Table D.4-6). Migrating mysticetes sometimes responded by changing their route away from the deterrent (Dunlop et al., 2013; Frankel & Stein, 2020; Watkins & Schevill, 1975) or not at all (Harcourt et al., 2014; Morton & Symonds, 2002; Pirotta et al., 2016). Other behavioral responses caused by acoustic alarms and deterrents include reduced foraging dives, path predictability and reoxygenation rages, as well as increased swim speeds and dive durations (Boisseau et al., 2021; Nowacek et al., 2004a).

Table D.4-6: Major Findings from Studies of Acoustic Alarms and Acoustic Deterrent Devices (ADDs) in Mysticetes

Species	***Major Finding***	***Supporting Studies***
Humpback whales – wild	Changed migration course away from the deterrent (more offshore) and surfaced more frequently during 2 kHz tones.	Dunlop et al. (2013); Watkins and Schevill (1975)
Gray whales – wild	Changed migration course away from the deterrent (towards shore) during stationary sonar transmissions (21 – 25 kHz, 148 dB re 1 µPa).	Frankel and Stein (2020)
Humpback whales – wild	No change in migration route or behavioral response (even within 500 m) during 2 – 5 kHz fisheries deterrents.	Harcourt et al. (2014); Morton and Symonds (2002); Pirotta et al. (2016)
North Atlantic right whales - wild	Interrupted foraging dives during particularly long acoustic alarm (0.5 – 4.5 kHz, several minute long).	Nowacek et al. (2004a)
Minke whales - wild	Increased speed, dive duration, path predictability (straighter paths), and decreased reoxygenation rates while foraging during ADD (15 kHz, 198 dB rms). Path predictability had strong relationship with received level. Speed and dive duration more influenced by the presence of the exposure signal instead of the received sound level.	Boisseau et al. (2021)

Notes: ADD = acoustic deterrent device; dB = decibel; kHz = kilohertz; m = meters; µPa = micropascal; rms = root mean square

Although some strong responses have been observed in mysticetes to sonar and other transducers (e.g., the single minke whale), for the most part mysticete responses appear to be fairly moderate across all received levels. While some responses such as cessation of foraging or changes in dive behavior could carry short-term impacts, in all cases behavior returned to normal after the signal stopped. Mysticete responses also seem to be highly mediated by behavioral state, with no responses occurring in some behavioral states, and contextual factors and signal characteristics having more impact than received level alone. Many of the contextual factors resulting from the behavioral response studies (e.g., close approaches by multiple vessels or tagging) would never be introduced in real Navy training scenarios. While data are lacking on behavioral responses of mysticetes to continuous active sonars, these species are known to be able to habituate to novel and continuous sounds (Nowacek et al., 2004a), suggesting that they are likely to have similar responses to high-duty cycle sonars. Therefore, mysticete behavioral responses to Navy sonar will likely be a result of the animal's behavioral state and prior experience rather than external variables such as ship proximity; thus, if significant behavioral responses occur they will likely be short term. In fact, no significant behavioral responses such as panic, stranding, or other severe reactions have been observed during monitoring of actual training exercises (Smultea et al., 2009; U.S. Department of the Navy, 2011b, 2014; Watwood et al., 2012).

D.4.5.1.2 Vessel Disturbance

Behavioral responses to vessels can be caused by multiple factors. It is difficult for researchers and analysts to separate the effects of vessel noise and vessel presence; therefore, this section will cover both aspects. Baleen whales demonstrate a variety of responses to vessel traffic and noise, including not responding at all to approaching vessels, as well as both horizontal (swimming away) and vertical (increased diving) avoidance (Baker et al., 1983; Fiori et al., 2019; Gende et al., 2011; Watkins, 1981). Avoidance responses can include changes in swim patterns, speed, or direction (Jahoda et al., 2003), staying submerged for longer periods of time (Au & Green, 2000), or performing shallower dives accompanied by more frequent surfacing. Smaller-scale responses to vessels include changes such as altered breathing patterns (e.g., Baker et al., 1983; Jahoda et al., 2003), and larger-scale changes such as a decrease in apparent presence (Anderwald et al., 2013). Other common behavioral reactions include changes in vocalizations, surface time, feeding and social behaviors (Au & Green, 2000; Dunlop, 2019; Fournet et al., 2018; Machernis et al., 2018; Richter et al., 2003; Williams et al., 2002a).

Certain vessel types come with additional associated sound, other than engine and propeller cavitation noise (e.g., icebreakers). Bowhead whales avoided the area around icebreaker ship noise and increased their time at the surface and number of blows (Richardson et al., 1995a). However, bowhead whales showed no discernable long-range (greater than 8 km) behavioral reaction to various types of vessel traffic, similar to their close relative, North Atlantic right whales (Martin et al., 2023b).

Studies show that North Atlantic right whales demonstrate little if any reaction to sounds of vessels approaching or the presence of the vessels themselves. They continue to use habitats in high vessel traffic areas (Nowacek et al., 2004a). This lack of response may be due to habituation to the presence and associated noise of vessels in right whale habitat or may be due to propagation effects that may attenuate vessel noise near the surface (Nowacek et al., 2004a; Terhune & Verboom, 1999). However, right whales have been reported to increase the amplitude or frequency of their vocalizations or call at a lower rate in the presence of increased vessel noise (Parks et al., 2007; Parks et al., 2011), and these vocalization changes may persist over long periods if background noise levels remained elevated.

Other species of mysticetes seem to lack obvious reactions to vessel disturbance as well, but it may be for lack of research or variables studied. Sei whales have been observed ignoring the presence of vessels entirely and even pass close to vessels (Reeves et al., 1998). Historically, fin whales tend to ignore vessels at a distance (Watkins, 1981) or habituate to vessels over time (Watkins, 1986), but still demonstrate vocal modifications (e.g., decreased frequency parameters of calls) during boat traffic. Fin whale calls in Ireland were less likely to be detected for every 1 dB re 1 µPa/minute increase in shipping noise levels as well (Ramesh et al., 2021). In the presence of tour boats in Chile, fin whales were changing their direction of movement more frequently, with less linear movement than occurred before the boats arrived; this behavior may represent evasion or avoidance of the boats (Santos-Carvallo et al., 2021). The increase in travel swim speeds after the boats left the area may be related to the rapid speeds at which the boats left the area, sometimes in front of the animals, leading to more avoidance behavior after the boats have left.

The likelihood of any behavioral response may be driven by the density, distance or approach of vessel traffic, the animal's behavioral state, or by the prior experience of the individual or population. If the threshold of disturbance is not met for a species or group of mysticetes, there may be no behavioral reaction, as seen during a study on fin and humpback whales that largely ignored vessels that remained 100 m or more away (Watkins, 1981). When a fishing vessel conducting an acoustic survey of pelagic fisheries began moving around six whales (species unknown) at close distances (50–400 m), whales only slightly changed swim direction (Bernasconi et al., 2012). In areas with high motorized vessel traffic, gray whales were likely to continue feeding when approached by a vessel, but in areas with less motorized vessel traffic they were more likely to change behaviors, either indicating habituation to vessels in high traffic area, or indicating possible startle reactions to close-approaching non-motorized vessels (e.g., kayaks) in quieter areas (Sullivan & Torres, 2018).

Changes in humpback whale behavior were also affected by vessel behavior (e.g., approach type, speed), in addition to time of day and season (Di Clemente et al., 2018; Fiori et al., 2019). Avoidance responses occurred most often after "J" type vessel approaches (i.e., traveling parallel to the whales' direction of travel, then overtaking the whales by turning in front of the group) compared to parallel or direct approaches. Mother humpbacks were particularly sensitive to direct and J type approaches and spent significantly more time diving in response (Fiori et al., 2019). The presence of a passing vessel did not change the behavior of resting humpback whale mother-calf pairs, but fast vessels with louder low-frequency weighted source levels of 173 dB re 1 µPa, equating to weighted received levels of 133 dB re 1 µPa at an average distance of 100 m, led to a decrease in resting behavior and increase in dives, swim speeds, and respiration rates (Sprogis et al., 2020). Humpback whale reactions to vessel disturbance were dependent on their behavioral state. When vessels came within 500 m humpbacks would continue to feed, but were more likely to start traveling if they were surface active when approached (Di Clemente et al., 2018).

Humpback whales changed their dive times, respiration rates, and social behavior when vessels were present. In a study of large Navy vessels in Hawaii, humpback whale avoidance behaviors included increasing dive times and decreasing respiration rates at the surface when vessels were within 0.5–2 km (Smultea et al., 2009). Social interactions between migrating males and mother-calf pairs were reduced in the presence of vessels towing seismic air gun arrays, regardless of whether the air guns were active or not; this indicates that it was the presence of ships (rather than the active air guns) that impacted humpback behavior (Dunlop et al., 2020).

The vocal behavior and communication space for humpback whales is also impacted by vessel disturbance. In one study, whales increased the source level of their calls with increased ambient noise levels that include vessel noise (Fournet et al., 2018) and in another humpback whale call rates increased in association with high vessel noise (Doyle et al., 2008). However, there are several studies demonstrating that the probability of humpback whale calls and detections decrease when vessel noise becomes a larger part of the soundscape (Fournet et al., 2018; Laute et al., 2022). When the number of whale watching trips decreased by nearly 70 percent in an Icelandic humpback whale feeding ground, the number of humpback whale calls doubled, even though the median ambient SPL did not change (Laute et al., 2022). Humpback song activity also decreased due to boat traffic near Brazil (Sousa-Lima &

Clark, 2008), and in Australia their communication area was reduced by half in average vessel-dominated noise (105 dB re 1 µPa). However the physical presence of vessels was the major contributing factor to decreased social interactions (Dunlop, 2019).

Examples of mysticete responses to tourism vessels, with an emphasis on humpback whale responses, are detailed in Table D.4-7.

Blue whale response to vessel disturbance varies from increasing the likelihood of producing certain types of calls when vessels pass (Melcón et al., 2012), to general avoidance behavior (Lesage et al., 2017; Szesciorka et al., 2019). In an area of high whale watch activity, vessels were within 2,000 m of blue whales 70 percent of the time, with a maximum of 8 vessels observed within 400 m of one whale at the same time. In response to repeated exposures to vessels, blue whales decreased time at the surface, had fewer breaths at the surface, shorter dive times and less time foraging as a result (Lesage et al., 2017). In response to an approaching large commercial vessel in an area of high ambient noise levels (125–130 dB re 1 µPa), a tagged female blue whale turned around mid-ascent and descended perpendicular to the ship's path (Szesciorka et al., 2019). The whale did not respond until the ship's closest point of approach (100 m distance, 135 dB re 1 µPa), which was 10 dB above the ambient noise levels. After the ship passed, the whale ascended to the surface again with a three-minute delay.

Table D.4-7: Examples of Behavioral Responses to Vessel Disturbance in Mysticetes

Species & Location	*Study*	*Boat type*	*Behavioral Change*					
			Feeding or foraging	*Surface behaviors*	*Resting*	*Respiration Rates*	*Diving duration*	*Horizontal avoidance (Δ direction or speed)*
Humpback whales – Hawaii	Baker et al. (1983)	Tour					↑ when < 2,000 m away	↑ when 2,000 – 4,000 m away
Humpback whales – Australia	Stamation et al. (2010)	Tour		↓		NC	↑	↑ or ↓ (avoid or approach)
Humpback whales – Alaska	Schuler et al. (2019); Toro et al. (2021)	Tour		↓		↑		↑
Minke whales – Iceland	Christiansen et al. (2013)	Tour	↓			↑ (↓ IBI)		
Blue whales – Canada	Lesage et al. (2017)	Tour	↓	↓		↓	↓	
Fin whales – Chile	Santos-Carvallo et al. (2021)	Tour						↑
Sperm whales – Portugal	Oliveira et al. (2022)	Tour	NC		↓ (↑ movement)			↑ speed of ascent
Southern right whales – Australia	Sprogis et al. (2023)	Tour			↓	NC		

Notes: ↑ = increase; ↓ = decrease; < = less than; Δ = change in; IBI = Inter-breath interval; m = meters; NC = no change

Minke whale negative, neutral, or positive response to vessels may be influenced by vessel speed and boat traffic density. In the Antarctic minke whales did not show any apparent response to a survey vessel moving at normal cruising speeds (about 12 knots) at a distance of 5.5 NM. However, when the vessel drifted or moved at very slow speeds (about 1 knot), many whales approached it (Leatherwood et al., 1982). Larger-scale negative changes like habitat displacement was found during a construction project in the United Kingdom, when fewer minke whales were observed as vessel traffic increased (Anderwald et al., 2013). Likewise, minke whales on feeding grounds in Iceland responded to increased whale watching vessel traffic with a decrease in foraging, both during deep dives and at the surface (Christiansen et al., 2013). They also increased their avoidance of the boats while decreasing their respiration rates, likely leading to an increase in their metabolic rates. Christiansen and Lusseau (2015) and Christiansen et al. (2014) followed up this study by modeling the cumulative impacts of whale watching boats on minke whales, but found that although the boats cause temporary feeding disruptions, there were not likely to be long-term consequences as a result. This suggests that short-term responses may not lead to long-term consequences and that over time animals may habituate to the presence of vessel traffic.

Longitudinal studies on vessel noise have been conducted, but the consequences of chronic vessel noise are not well understood. Using historical records, Watkins (1986) showed that the reactions of four species of mysticetes to vessel traffic and whale watching activities in Cape Cod had changed over 25-years (1957–1982). Reactions of minke whales changed from initially more positive reactions, such as coming towards the boat or research equipment to investigate, to more uninterested reactions towards the end of the study. Fin whales, the most numerous species in the area, showed a trend from initially more negative reactions, such as swimming away from the boat with limited surfacing, to more uninterested reactions (ignoring), allowing boats to approach within 30 m. Right whales showed little change over the study period, with a roughly equal number of reactions judged to be negative and uninterested; no right whales were noted as having positive reactions to vessels. Humpback whales showed a trend from negative to positive reactions with vessels during the study period. The author concluded that the whales had habituated to the human activities over time (Watkins, 1986).

Overall baleen whale responses to vessel noise and traffic are varied, and habituation or changes to vocalization are predominant long-term responses. When baleen whales do avoid ships, they do so by altering their swim and dive patterns to move away from the vessel. In many cases the whales do not appear to change their behavior at all. This may result from habituation by the whales but may also result from reduced received levels near the surface due to propagation, or due to acoustic shadowing of the propeller cavitation noise by the ship's hull. Although a lack of response in the presence of a vessel may minimize potential disturbance from passing ships, it does increase the whales' vulnerability to vessel strike, which may be of greater concern for baleen whales than vessel noise.

D.4.5.1.3 Aircraft Disturbance

Mysticetes either ignore or occasionally dive in response to aircraft overflights (Koski et al., 1998). Richardson et al. (1985); Richardson et al. (1995b) found no evidence that single or occasional aircraft flying above mysticetes causes long-term displacement of these mammals. However, bowhead whales in the Beaufort Sea exhibited a short-term behavioral response to fixed-wing aircraft and vessels. Reactions were frequently observed at less than 1,000 ft. above sea level, infrequently observed at 1,500 ft., and not observed at all at 2,000 ft. (Richardson et al., 1985).

Bowhead whales reacted to helicopter overflights by diving, breaching, changing direction or behavior, and altering breathing patterns. Behavioral reactions decreased in frequency as the altitude of the helicopter increased to 150 m or higher. The bowheads exhibited fewer behavioral changes than did the odontocetes in the same area (Patenaude et al., 2002). It should be noted that bowhead whales in this study may have more acute responses to anthropogenic activity than many other marine mammals since these animals were presented with restricted egress due to limited open water between ice floes. Additionally, these animals are hunted by Alaska Natives, which could lead to animals developing additional sensitivity to human noise and presence.

Studies on unmanned aerial systems have not found significant behavioral responses from mysticetes so far. These devices are much smaller and quieter than typical aircraft, and so are less likely to cause a behavioral response, although they may fly at much lower altitudes (Smith et al., 2016). Acevedo-Whitehouse et al. (2010) maneuvered a remote controlled helicopter over large baleen whales to collect samples of their blows, with no more avoidance behavior than noted for typical photo-identification vessel approaches. Bowhead whales did not respond to an unmanned system flying at altitudes between 120 and 210 m above the ocean's surface (Koski et al., 2015; Koski et al., 1998). While collecting humpback photogrammetry and fitness data, Christiansen et al. (2016) did not observe any responses to their unmanned aerial vehicle flown 30–120 m above the water either. Even 10 southern right whale mother-calf pairs showed no change in swim speed, respiration rate, turning angle, or interbreath interval in response to an unmanned aerial vehicle (Christiansen et al., 2020). Some of the animals were equipped with DTAGs to measure the sound of the unmanned aerial vehicle; the received levels in the 100–1,500 Hz band were 86 ± 4 dB re 1 µPa, very similar to ambient noise levels measured at 81 ± 7 dB in the same frequency band.

D.4.5.1.4 Impulsive Noise

Baleen whales have shown a variety of responses to impulsive sound sources, including avoidance, aggressive directed movement towards the source, reduced surface intervals, altered swimming behavior, and changes in vocalization rates (Gordon et al., 2003; McCauley et al., 2000a; Richardson et al., 1985; Southall et al., 2007). Studies have been conducted on many baleen whale species, including gray, humpback, blue, fin and bowhead whales; it is assumed that these responses are representative of all baleen whale species. The behavioral state of the whale seems to be an integral part of whether the animal responds and how they respond, as does the location and movement of the sound source, more than the received level of the sound.

Migratory behavior seems to lead to a higher likelihood of response, with some species demonstrating more sensitivity than others do. For example, migrating gray whales showed avoidance responses to seismic vessels at received levels between 164 and 190 dB re 1 µPa (Malme et al., 1986, 1988). Similarly, migrating humpback whales showed avoidance behavior at ranges of 5–8 km from a seismic array during observational studies and controlled exposure experiments in one Australian study (McCauley et al., 1998), and in another Australian study decreased their dive times and reduced their swimming speeds (Dunlop et al., 2015). However, when comparing received levels and behavioral responses using ramp-up versus a constant noise level of air guns, humpback whales did not change their dive behavior but did deviate from their predicted heading and decreased their swim speeds (Dunlop et al., 2016). In addition, the whales demonstrated more course deviation during the constant source trials but reduced travel speeds more in the ramp-up trials; in either case there was no dose-response relationship with the received level of the air gun noise, and similar responses were observed in control trials with vessel movement but no air guns so some of the response was likely due to the presence of the vessel and not the received level of the air guns. Similar results were found in migrating humpback whales (Dunlop et al., 2020). Social interactions between males and mother-calf pairs were reduced in the presence of vessels towing seismic air gun arrays, regardless of whether the air guns were active or not; this indicates that it was the presence of ships (rather than the active air guns) that impacted humpback behavior (Dunlop et al., 2020).

When looking at the relationships between proximity, received level, and behavioral response, Dunlop et al. (2017) used responses to two different air guns and found responses occurred more towards the smaller, closer source than to the larger source at the same received level, demonstrating the importance of proximity. Responses were found to be more likely when the source was within 3 km or above 140 dB re 1 µPa, although responses were variable and some animals did not respond at those values while others responded below them. In addition, responses were generally small, with short term course deviations of only around 500 m (Dunlop et al., 2017). McDonald et al. (1995) tracked a blue whale with seafloor seismometers and reported that it stopped vocalizing and changed its travel direction at a range of 10 km from the seismic vessel (estimated received level 143 dB re 1 µPa peak-to-peak). Bowhead whales seem to be the most sensitive species. While most bowhead whales did not show active avoidance until within 8 km of seismic vessels (Richardson et al., 1995b), some whales avoided vessels by more than 20 km at received levels as low as 120 dB re 1 µPa. Additionally, Malme et al. (1988) observed clear changes in diving and breathing patterns in bowheads at ranges up to 73 km from seismic vessels, with received levels as low as 125 dB re 1 µPa. Bowhead whales may also avoid the area around seismic surveys, from 6 to 8 km (Koski and Johnson 1987, as cited in Gordon et al., 2003) out to 20 or 30 km (Richardson et al., 1999). However, work by Robertson et al. (2013) supports the idea that behavioral responses are contextually dependent, and that during seismic operations bowhead whales may be less “available” for counting due to alterations in dive behavior but that they may not have left the area after all.

In contrast, noise from seismic surveys was not found to impact feeding behavior or exhalation rates in western gray whales while resting or diving off the coast of Russia (Gailey et al., 2007; Yazvenko et al., 2007); however, the increase in vessel traffic associated with the surveys and the proximity of the vessels to the whales did affect the orientation of the whales relative to the vessels and shortened their dive-surface intervals (Gailey et al., 2016). They also increased their speed and distance from the noise source, and will even travel towards shore to avoid an approaching seismic vessel, as shown in one case study (Gailey et al., 2022). Todd et al. (1996) found no clear short-term behavioral responses by foraging humpbacks to explosions associated with construction operations in Newfoundland but did see a trend of increased rates of net entanglement closer to the noise source, possibly indicating a reduction in net detection associated with the noise through masking or TTS. Distributions of fin and minke whales were modeled with a suite of environmental variables along with the occurrence or absence of seismic surveys, and no evidence of a decrease in sighting rates relative to seismic activity was found for either species (Vilela et al., 2016). Their distributions were driven entirely by environmental variables, particularly those linked to prey including warmer sea surface temperatures, higher chlorophyll-a values, and higher photosynthetically available radiation (a measure of primary productivity). Sighting rates based on over 8,000 hours of baleen and toothed whale survey data were compared on regular vessel surveys versus both active and passive periods of seismic surveys (Kavanagh et al., 2019). Models of sighting numbers were developed, and it was determined that baleen whale sightings were reduced by 88 and 87 percent during active and inactive phases of seismic surveys, respectively, compared to regular surveys. These results seemed to occur regardless of geographic location of the survey; however, when only comparing active versus inactive periods of seismic surveys the geographic location did seem to affect the change in sighting rates.

Vocal and other behavioral responses to seismic surveys have been observed in a number of baleen whale species, including a cessation of calling, a shift in frequency, increases in amplitude or call rate, leaving the area, or a combination of these strategies (Blackwell et al., 2013; Blackwell et al., 2015; Blackwell et al., 2017; Di Lorio & Clark, 2010). For example, responses by fin whales to a 10-day seismic survey in the Mediterranean Sea included possible decreased call production and movement away from the area (Castellote et al., 2012). Models of humpback whale song showed a decrease in the number of singers with increasing received levels of air gun pulses, indicating either a vocal modification or that whales left the area (Cerchio et al., 2014).

Mysticetes seem to be the most behaviorally sensitive taxonomic group of marine mammals to impulsive sound sources, with possible avoidance responses occurring out to 30 km and vocal changes occurring in response to sounds over 100 km away. However, they are also the most studied taxonomic group, yielding a larger sample size and greater chance of finding behavioral reactions to impulsive noise. Also, their responses appear to be behavior-dependent, with most avoidance responses occurring during migration behavior and little observed response during feeding behavior. These response patterns are likely to hold true for Navy impulsive sources; however, Navy impulsive sources would largely be stationary (e.g., explosives fired at a fixed target), and short term (on the order of hours rather than days or weeks) than were found in these studies and so responses would likely occur in closer proximity or not at all.

D.4.5.2 Behavioral Reactions of Odontocetes

D.4.5.2.1 Sonar and Other Transducers

D.4.5.2.1.1 Beaked Whales

Following several beaked whale strandings in which military mid-frequency active sonar was identified as a contributing cause or factor, the scientific community hypothesized that these deep-diving species may be more susceptible to behavioral disturbance or behaviorally mediated physiological consequences. Subsequently, behavioral response studies in which beaked whales were intentionally or incidentally exposed to real or simulated sonar, in some cases on military ranges, found that beaked whales are likely more sensitive to disturbance than most other cetaceans. Observed reactions by Blainville's beaked whales, Baird's beaked whales, goose-beaked whales (formerly known as Cuvier's beaked whales), and northern bottlenose whales (the largest of the beaked whales), to mid-frequency sonar sounds include cessation of clicking, decline in group vocal periods, termination of foraging dives, changes in direction to avoid the sound source, slower ascent rates to the surface, longer deep and shallow dive durations, and other unusual dive behaviors (DeRuiter et al., 2013b; Hewitt et al., 2022; Jacobson et al., 2022; McCarthy et al., 2011; Miller et al., 2015; Moretti et al., 2014; Southall et al., 2011; Stimpert et al., 2014; Tyack et al., 2011).

Research on beaked whales includes detailed response data from exposures of focal, tagged animals, as well as wide-scale analyses of changes in group vocal behaviors across instrumented ranges. Many of the exposures to tagged animals occurred within 1–8 km of the focal animal, within a few hours of tagging the animal, and with one or more boats within a few kilometers to observe responses and record acoustic data. Thus, while tagged animal data is precise and detailed, the animal's behavior may be influenced by the experimental context. In addition, individual variability can only be assessed with many tagged individuals. In contrast, group vocal behavior observations from instrumented ranges do not provide fine-scale movement and behavior data for individuals but allow for assessing responses across a range-wide population in real-world military training conditions.

Beaked whales have been tagged and exposed to sonar across multiple efforts (e.g., AUTEC, 3S2, SOCAL BRS, Atlantic BRS). During the SOCAL BRS, a tagged Baird's beaked whale exposed to simulated mid-frequency active sonar within 3 km increased swim speed and modified its dive behavior (Stimpert et al., 2014). One goose-beaked whale was also incidentally exposed to real Navy sonar located over 100 km away in addition to the source used in the controlled exposure study, and the authors did not detect similar responses at comparable received levels. Received levels from the mid-frequency active sonar signals from the controlled (3.4-9.5 km) and incidental (118 km) exposures were calculated as 84–144 and 78–106 dB re 1 µPa, respectively, indicating that context of the exposures (e.g., source proximity, controlled source ramp-up) may have been a significant factor in the responses to the simulated sonars (DeRuiter et al., 2013b).

Long-term tagging work on the SOCAL BRS has demonstrated that the longer duration dives considered a behavioral response by DeRuiter et al. (2013b) fell within the normal range of dive durations found for eight tagged goose-beaked whales on the Southern California Offshore Range (Schorr et al., 2014). However, the longer inter-deep dive intervals found by DeRuiter et al. (2013b), which were among the longest found by Schorr et al. (2014) and Falcone et al. (2017), could indicate a response to sonar. In addition, Williams et al. (2017) note that in normal deep dives or during fast swim speeds, beaked whales and other marine mammals use strategies to reduce their stroke rates, including leaping or wave surfing when swimming, and interspersing glides between bouts of stroking when diving. They determined that in the post-exposure dives by the tagged goose-beaked whales described in DeRuiter et al. (2013b), the whales ceased gliding and swam with almost continuous strokes. This change in swim behavior was calculated to increase metabolic costs about 30.5 percent and increase the amount of energy expending on fast swim speeds from 27 to 59 percent of their overall energy budget. This repartitioning of energy was detected in the model up to 1.7 hours after the single sonar exposure. Therefore, while the overall post-exposure dive durations were similar, the metabolic energy calculated by Williams et al. (2017) was higher. However, Southall et al. (2019a) found that prey availability was higher in the western area of the Southern California Offshore Range where goose-beaked whales preferentially occurred, while prey resources were lower in the eastern area and moderate in the area just north of the Range. This high prey availability may indicate that fewer foraging dives are needed to meet metabolic energy requirements than would be needed in another area with fewer resources.

During the 3S2 Project, the roles of sound source distance and received level in northern bottlenose whales were analyzed in an environment without frequent sonar activity using controlled exposure experiments (von Benda-Beckmann et al., 2019; Wensveen et al., 2019). Researchers observed behavioral avoidance of the sound source over a wide range of distances (0.8–28 km) and estimated avoidance thresholds ranging from received SPLs of 117–126 dB re 1 µPa. The behavioral response characteristics and avoidance thresholds were comparable to those previously observed in beaked whale studies; however, they did not observe an effect of distance on behavioral response and found that onset and intensity of behavioral response were better predicted by received SPL. One northern bottlenose whale did approach the ship and circle the source, then resumed foraging after the exposure, but the source level was only 122 dB re 1 µPa. A northern bottlenose whale conducted the longest and deepest dive on record for that species after sonar exposure and continued swimming away from the source for over seven hours (Miller et al., 2015; Siegal et al., 2022; Wensveen et al., 2019).

On the AUTEC range, Blainville's beaked whales located on-range appear to move off-range during sonar use and return only after the sonar transmissions have stopped, sometimes taking several days to do so (Boyd et al., 2009; Henderson et al., 2015; Jones-Todd et al., 2021; Manzano-Roth et al., 2022; Manzano-

Roth et al., 2016; McCarthy et al., 2011; Tyack et al., 2011). For example, five Blainville's beaked whales that were estimated to be within 2–29 km of the AUTEC range at the onset of sonar were displaced a maximum of 28–68 km from the range after moving away from the range, although one whale approached the range during the period of active sonar. Researchers found a decline in deep dives at the onset of the training and an increase in time spent on foraging dives as individuals moved away from the range. Predicted received levels at which presumed responses were observed were comparable to those previously observed in beaked whale studies. Acoustic data indicated that vocal periods were detected on the range within 72 hours after training ended (Joyce et al., 2019). However, Blainville's beaked whales remain on the range to forage throughout the rest of the year (Henderson et al., 2016), possibly indicating that this a preferred foraging habitat regardless of the effects of the noise, or it could be that there are no long-term consequences of the sonar activity. Similarly, photo-identification studies in the SOCAL Range Complex have identified approximately 100 individual goose-beaked whale individuals, with 40 percent having been seen in one or more prior years, with re-sightings up to seven years apart, indicating a possibly resident population on the range (Falcone & Schorr, 2014; Falcone et al., 2009).

The probability of Blainville's beaked whale group vocal periods on the Pacific Missile Range Facility were modeled during periods of no naval activity, naval activity without hull-mounted mid-frequency active sonar, and naval activity with hull-mounted mid-frequency active sonar (Jacobson et al., 2022). At a received level of 150 dB re 1 µPa rms (root mean square), the probability of group vocal period detection decreased by 77 percent compared to periods when general training activity was ongoing and by 87 percent compared to baseline conditions. This study found a greater reduction in probability of a group vocal period with mid-frequency active sonar than observed in a prior study of Blainville's beaked whales at AUTEC (Moretti et al., 2014). The authors suggest that this may be due to the baseline period in the AUTEC study including naval activity without mid-frequency active sonar, potentially lowering the baseline group vocal period activity in that study, or due to differences in the residency of the populations at each range. Along the edge of the Scotian Shelf off eastern Canada, baseline activity from both prior to a period of naval sonar use and a prior year with no known naval activity were used to assess changes in beaked whale detections. Mesoplodant and goose-beaked whale detection rates dropped both during and after an eight-day, multi-platform anti-submarine warfare training exercise, and remained low seven days after the exercise (Stanistreet et al., 2022).

On the Southern California Anti-Submarine Warfare Range, deep and shallow dive durations, surface interval durations, and inter-deep dive intervals of goose-beaked whales were modeled against predictor values that included helicopter dipping, mid-power mid-frequency active sonar and hull-mounted, high-power mid-frequency active sonar along with other, non-mid-frequency active sonar predictors (Falcone et al., 2017). They found both shallow and deep dive durations increased as the proximity to both mid- and high-powered sources decreased and that surface intervals and inter-deep dive intervals increased in the presence of both types of sonars, although surface intervals shortened during periods of no mid-frequency active sonar. The responses to the mid-power mid-frequency active sonar at closer ranges were comparable to the responses to the higher source level ship sonar, again highlighting the importance of proximity. This study also supports context as a response factor, as helicopter dipping sonars are shorter duration and randomly located, so more difficult for beaked whales to predict or track and therefore potentially more likely to cause a response, especially when they occur at closer distances (6–25 km in this study). Sea floor depths and quantity of light are also important variables to consider in goose-beaked whale behavioral response studies, as their foraging dive depth increased with sea floor depth up to sea floor depths of 2,000 m. The fraction of time spent at foraging depths and likely foraging was greater at night, although they spent more time near the surface during the night as well, particularly on dark nights with little moonlight, likely avoiding predation by staying deeper during periods of bright lunar illumination (Barlow et al., 2020). Sonar occurred during 10 percent of the dives studied and had little effect on the resulting dive metrics. Watwood et al. (2017) found that helicopter dipping events occurred more frequently but with shorter durations than periods of hull-mounted sonar, and also found that the longer the duration of a sonar event, the greater reduction in detected goose-beaked whale group dives. Therefore, when looking at the number of detected group dives there was a greater reduction during periods of hull-mounted sonar than during helicopter dipping sonar. Similar results were found by DiMarzio et al. (2019).

Echosounders

Beaked whales may respond similarly to shipboard echosounders, commonly used for navigation, fisheries, and scientific purposes, with frequencies ranging from 12 to 400 kHz and source levels up to 230 dB re 1 µPa but typically a very narrow beam (Cholewiak et al., 2017). During a scientific cetacean survey, an array of echosounders was used in a one-day-on, one-day-off paradigm. Beaked whale acoustic detections occurred predominantly (96 percent) when the echosounder was off, with only 4 detections occurring when it was on. Beaked whales were sighted fairly equally when the echosounder was on or off, but sightings were further from the ship when the echosounder was on (Cholewiak et al., 2017). These findings indicate that the beaked whales may be avoiding the area and may cease foraging near the echosounder. Another study also found that echosounders contributed to fewer beaked whale observations, but ultrasonic antifouling devices elicited an even stronger avoidance response (Trickey et al., 2022).

In contrast, goose-beaked whale group vocal periods during multibeam echosounder activity recorded in the Southern California Antisubmarine Warfare Range did not decrease during the echosounder survey (Varghese et al., 2020). The whales did not leave the range or cease foraging, and group vocal periods increased during and after multibeam echosounder surveys. Since echosounders are highly directional and the sound doesn't propagate horizontally, the difference in these results may be due to the locations of beaked whales relative to the echosounder. In fact, one of the surveys by Varghese et al. (2020) was largely conducted on a portion of the range little used by goose-beaked whales. A subsequent analysis suggested that the observed spatial shifts were most likely due to prey dynamics (Varghese et al., 2021).

Predator Sounds

Tyack et al. (2011) hypothesized that beaked whale responses to sonar may represent an anti-predator response. To test this idea, vocalizations of a potential predator—a killer whale—were played back to a Blainville's beaked whale at AUTEC. The killer whale vocalization recording was from a stock of mammal-eating killer whales that are not present at AUTEC. This exposure resulted in a similar but more pronounced reaction than that elicited by sonar playback, which included longer inter-dive intervals and a sustained straight-line departure of more than 20 km from the area (Allen et al., 2014; Tyack et al., 2011). Similarly, De Soto et al. (2020) hypothesized that the high degree of vocal synchrony in beaked whales during their deep foraging dives, coupled with their silent, low-angled ascents, have evolved as an anti-predator response to killer whales. Since killer whales do not dive deep when foraging and so may be waiting at the surface for animals to finish a dive, these authors speculated that by diving in spatial and vocal cohesion with all members of their group, and by surfacing silently and up to 1 km away from where they were vocally active during the dive, they minimize the ability of killer whales to locate them when at the surface. This may lead to a trade-off for the larger, more fit individuals that can conduct longer foraging dives, such that all members of the group remain together and are better protected by this behavior. The authors speculate that this may explain the long, slow, silent, and shallow ascents that beaked whales make when sonar occurs during a deep foraging dive. However, these hypotheses are based only on the dive behavior of tagged beaked whales, with no observations of predation attempts by killer whales, and "anti-predator response" theory needs to be tested further to be validated. This anti-predator hypothesis was also tested by playing back killer whale vocalizations to northern bottlenose whales and several other odontocetes to determine responses by both potential prey and conspecifics (Miller, 2012; Miller et al., 2011). Results varied in other odontocetes, from no response to an increase in group size and attraction to the source (Curé et al., 2012). Changes in foraging duration during killer whale playbacks and mid-frequency sonar were positively correlated across four species in the 3S Norwegian studies, including northern bottlenose whales, suggesting that tolerance of predation risk may play a role in sensitivity to sonar disturbance (Miller et al., 2022).

D.4.5.2.1.2 Harbor Porpoises

There are very few behavioral response studies on harbor porpoise reactions to sonar, but there are many reports of porpoise responding to other tonal sounds such as acoustic harassment devices (AHDs) and acoustic deterrent devices (ADDs). AHDs and ADDs, which transmit sound into the acoustic environment like Navy sources, have been used to deter marine mammals from fishing gear both to prevent entanglement and to reduce depredation (taking fish). These devices have been used successfully to deter harbor porpoises and beaked whales from getting entangled in fishing nets. See Table D.4-8 for a summary of the major findings from studies of the effects of AHDs and ADDs in harbor porpoises.

Table D.4-8: Major Findings from Studies of Acoustic Harassment Devices (AHDs) and Acoustic Deterrent Devices (ADDs) in Harbor Porpoises

Major Finding	*Supporting Studies*
High-frequency acoustic alarms with varied duration, interval, and sweep characteristics can prove to be effective deterrents for harbor porpoises.	Kastelein et al. (2006); Kastelein et al. (2001); Kastelein et al. (2017)
Detection rates were reduced by ADDs, especially in close proximity (< 100 m away, limited to a few 100 m at most). Tested with many pinger parameters (e.g., 10 kHz tone with and without 30 to 60 kHz sweep, 50 – 120 kHz).	Kindt-Larsen et al. (2019); Kyhn et al. (2015); Omeyer et al. (2020); {Findlay, 2024, `#23654@@author-year}
Simulated AHD (12 kHz, 165 dB re 1 µPa) caused avoidance (physically moved away) from the source up to 525 m.	Mikkelsen et al. (2017)
Detection rates within 100 m were reduced by banana pingers designed to avoid pinniped responses, but had no effect at 400 m.	Königson et al. (2021)
Habituation to short-term exposures (2 to 4 exposures).	Kyhn et al. (2015)
No habituation (remained avoidant/silent) while pingers were on, especially over longer-term exposures (28+ days).	Kyhn et al. (2015); Omeyer et al. (2020)
Habituation to a pinger may occur with single tones but is less likely with a mixture of signals.	Kindt-Larsen et al. (2019)
When pinger was shut off, clicking returned to normal levels (no long-term displacement).	Omeyer et al. (2020)
Modeled results found that when pingers were used alone (in the absence of gillnets or time-area closures), caused enough habitat displacement for 21% population-level reduction.	van Beest et al. (2017)

Major Finding	*Supporting Studies*
Net pingers are successful at reducing entanglements for harbor porpoise and beaked whales since these species are not depredating from the nets but are getting entangled when foraging in the area and are unable to detect the net.	Carretta et al. (2008); Schakner and Blumstein (2013)
Lower broadband source SPL, SEL, and duty cycle "startle sounds" compared to other ADDs resulted in avoidance behaviors for duration of exposure (+ 31 minutes minimum). Travelled at least 1 km (> 3 km maximum) within 15 minutes of exposure, increased group cohesion and swim speed away from the transducer.	Hiley et al. (2021)
Avoided high-frequency ADDs (60 – 150 kHz, 172 dB re 1 μPa rms) up to 2.5 km away. Reduced occurrence by 30 to 100% at 750 m.	Voß et al. (2023)
Swam quickly away from low received level AHDs (14 kHz, 98-132 dB re 1 μPa), decreased echolocation rate, and either increased or decreased heart rate. Waited 15 – 42 minutes to resume feeding behavior.	Elmegaard et al. (2023) Elmegaard et al. (2021)

Notes: % = percent; > = greater than; < = less than; ADD = acoustic deterrent device; AHD = acoustic harassment device; dB = decibel; kHz = kilohertz; km = kilometer; m = meters; μPa = micropascal; SEL = sound exposure level; SPL = sound pressure level

Behavioral responses by harbor porpoises to a variety of sound sources other than acoustic alarms have been studied (Kastelein et al., 2006; Kastelein et al., 2001), including emissions for underwater data transmission (Kastelein et al., 2005b), and tones such as 1–2 kHz and 6–7 kHz sweeps with and without harmonics (Kastelein et al., 2014c), 25 kHz tones with and without sidebands (Kastelein et al., 2015e; Kastelein et al., 2015f), and mid-frequency sonar tones at 3.5–4.1 kHz at 2.7 percent and 96 percent duty cycles (e.g., one tone per minute versus a continuous tone for almost a minute) (Kastelein et al., 2018b). Responses include increased respiration rates, swim speed, jumping, swimming further from the source, or decreasing echolocation rate which increases risk of wild harbor porpoise becoming by-catch (Elmegaard et al., 2021). However, responses were different depending on the source. For example, harbor porpoises responded to the 1–2 kHz upsweep at 123 dB re 1 μPa, but not to the downsweep or the 6–7 kHz tonal at the same level (Kastelein et al., 2014c). When measuring the same sweeps for a startle response, the 50 percent response threshold was 133 and 101 dB re 1 μPa for 1–2 kHz and 6–7 kHz sweeps, respectively, when no harmonics were present, and decreased to 90 dB re 1 μPa for 1–2 kHz sweeps with harmonics present (Kastelein et al., 2014c).

Kastelein et al. (2019a) examined the potential masking effect of high sea state ambient noise on captive harbor porpoise perception of and response to high duty cycle playbacks of AN/SQS-53C sonar signals by observing their respiration rates. Results indicated that sonar signals were not masked by the high sea state noise, and received levels at which responses were observed were similar to those observed in prior studies of harbor porpoise behavior. However, in another study sonar sweeps did not elicit a startle response in captive harbor porpoises; instead initial exposures induced bradycardia (slowing of the heart rate), with subsequent habituation that was conserved for at least three years (Elmegaard et al., 2021).

Harbor porpoises did not respond to the low-duty cycle mid-frequency tones at any received level, but one did respond to the high-duty cycle signal with more jumping and increased respiration rates (Kastelein et al., 2018b). Harbor porpoises responded to seal scarers with broadband signals up to 44 kHz with a slight respiration response at 117 dB re 1 μPa and an avoidance response at 139 dB re 1 μPa, but another scarer with a fundamental (strongest) frequency of 18 kHz did not have an avoidance response until 151 dB re 1 μPa (Kastelein et al., 2015d). Exposure of the same acoustic pinger to a striped dolphin under the same conditions did not elicit a response (Kastelein et al., 2006), again highlighting the importance in understanding species differences in the tolerance of underwater noise, although sample sizes in these studies was small so these could reflect individual differences as well.

D.4.5.2.1.3 Other Odontocetes

While there has been a focus on beaked whale (and to a lesser extent harbor porpoise) response to sonar and similar transducers, other species have been studied during behavioral response studies as well, including pilot whales, killer whales, sperm whales, false killer whales, melon-headed whales, bottlenose dolphins, rough-toothed dolphins, Risso's dolphins, Pacific white-sided dolphins, short-beaked common dolphins, long-beaked common dolphins, and Commerson's dolphins. Responses by these species include horizontal avoidance, changes in swim speed, changes in whistle rate, reduced breathing rates, changes in behavioral state, and changes in dive behavior {Miller, 2011, `#2665;Miller, 2012, `#11533;Miller, 2014, `#11532;Antunes, 2014, `#8942;Isojunno, 2017, `#15703;Isojunno, 2018, `#15705;Isojunno, 2020, `#16395;Casey, 2024 #16185}{Southall, 2024, `#23640}. Some species like pilot whales, false killer whales and Risso's dolphins will also respond by mimicking the sound of the sonar with their whistles (Alves et al., 2014; DeRuiter et al., 2013a; Smultea et al., 2012).

More severe behavioral responses, such as separation of a killer whale calf from its group, have been observed during exposure to mid-frequency sonar playbacks (Miller et al., 2011). However, it is difficult to tease this response to sonar apart from the animals' response to the perusing research vessel in an environment with limited egress. Received level thresholds at the onset of avoidance behavior were generally lower for killer whales (mean 129 dB re 1 µPa) compared to pilot whales (mean 150 dB re 1 µPa) and sperm whales (mean 140 dB re 1 µPa) (Antunes et al., 2014; Curé et al., 2021; Miller, 2012; Miller et al., 2014). Tagged odontocetes (e.g., pilot whales, rough-toothed dolphins, bottlenose dolphins, and false killer whales) did not have an avoidance response to sonar on or near the Pacific Missile Range Facility before Navy training events (Baird et al., 2014; Baird et al., 2017; Baird et al., 2013). In some cases, odontocetes even traveled towards areas of higher noise levels, while estimated received SPLs varied from 130 to 168 dB re 1 µPa and distances from sonar sources ranged between 3.2 and 94.4 km.

Not all responses to sonar cause avoidance responses or deleterious changes in behavior. Navy exercises involving sonar on large ships may also attract odontocetes or cause no reaction, depending on the species. While most of the published literature involving bowriding odontocete observations does not involve sonar, certain species (e.g., bottlenose, spotted, spinner, Clymene, Pacific white sided, rough-toothed dolphins) will sometimes approach vessels to bow ride, indicating either that these species are less sensitive to vessels or that the behavioral drive to bow ride supersedes any impact of the associated noise (Würsig et al., 1998). During aerial and visual monitoring of Navy training events, rough-toothed dolphins and unidentified dolphins were observed approaching the vessel with active sonar as if to bow ride. Spotted dolphins were observed nearby but did not avoid or approach the vessel (Mobley, 2011; U.S. Department of the Navy, 2011a; Watwood et al., 2012). During small boat surveys near the Southern California Offshore Range in southern California, more dolphins were encountered in June compared to a similar survey conducted the previous November after seven days of mid-frequency sonar activity; it was not investigated if this change was due to the sonar activity or was due to the poor weather conditions in November that may have prevented animals from being seen (Campbell et al., 2010). There were also fewer passive acoustic dolphin detections during and after longer sonar activities in the Mariana Islands Range Complex, with the post-activity absence lasting longer than the mean dolphin absence of two days when sonar was not present (Munger et al., 2014; Munger et al., 2015).

Controlled experiments have also been conducted on captive animals to estimate received levels at which behavioral responses occur. In one study, bottlenose dolphin behavioral responses were recorded when exposed to 3 kHz sonar-like tones between 115 and 185 dB re 1 μPa (Houser et al., 2013a), and in another study bottlenose dolphins and beluga whales were presented with one-second tones up to 203 dB re 1 μPa to measure TTS (Finneran et al., 2003a; Finneran et al., 2001; Finneran et al., 2005; Finneran & Schlundt, 2004; Schlundt et al., 2000). During these studies, responses included changes in respiration rate, fluke slaps, and a refusal to participate or return to the location of the sound stimulus. This refusal included what appeared to be deliberate attempts to avoid a sound exposure or to avoid the location of the exposure site during subsequent tests (Finneran et al., 2002; Schlundt et al., 2000). In the behavioral response study, bottlenose dolphins demonstrated a 50 percent probability of response at 172 dB re 1 μPa over 10 trials. In the TTS experiment, bottlenose dolphins exposed to one-second intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μPa; beluga whales did so at received levels of 180 to 196 dB re 1 μPa and above. In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway et al., 1997; Schlundt et al., 2000). While animals were commonly reinforced with food during these studies, the controlled environment provided insight on received levels at which animals behaviorally respond to noise sources.

There are opportunistic observations of behavioral responses to sonar as well, although in those cases it is difficult to attribute observed responses directly to the sonar exposure, or to know exactly what form the response took. For example, both sperm and pilot whales potentially ceased sound production during the Heard Island feasibility test, with transmissions centered at 57 Hz and up to 220 dB re 1 µPa (Bowles et al., 1994), although it could not be determined whether the animals ceased sound production or left the area. Killer whales in Haro Strait exhibited what were believed by some observers to be aberrant behaviors, during a time that the USS Shoup was in the vicinity and engaged in mid-frequency active sonar operations. Sound fields modeled for the USS Shoup transmissions (Fromm, 2009; National Marine Fisheries Service, 2005; U.S. Department of the Navy, 2004) estimated a mean received SPL of approximately 169 dB re 1 µPa at the location of the killer whales at the closest point of approach between the animals and the vessel (estimated received SPLs ranged from 150 to 180 dB re 1 µPa). However, attributing the observed behaviors to any one cause is problematic given there were six nearby whale watch vessels surrounding the pod, and subsequent research has demonstrated that "Southern Residents modify their behavior by increasing surface activity (breaches, tail slaps, and pectoral fin slaps) and swimming in more erratic paths when vessels are close" (National Oceanic and Atmospheric Administration, 2014).

Opportunistic sightings of several other odontocete species (i.e., bottlenose dolphins, Risso's dolphins, Pacific white-sided dolphins, common dolphins) have been observed near the Southern California Offshore Range during periods of mid-frequency active sonar. Responses included changes in or cessation of vocalizations, changes in behavior, and leaving the area, and at the highest received levels animals were not present in the area at all (Henderson et al., 2014). However, these opportunistic observations were conducted from a vessel off-range, and so any observed responses could not be attributed to the sonar with any certainty. Similarly, research on sperm whales in the Caribbean in 1983 coincided with the U.S. intervention in Grenada, where animals were presumed to scatter and leave the area because of military sonar (Watkins et al., 1985; Watkins & Schevill, 1975). They also reported similar reactions from noise generated by banging on their boat hull; therefore, it was unclear if the sperm whales were reacting to the sonar signal itself or to a potentially new unknown sound in general.

Behavioral responses by odontocetes to sonar and other transducers appear to range from no response at all to responses that could potentially lead to long-term consequences for individual animals (e.g., mother-calf separation). This is likely in part because this taxonomic group is so broad and includes some of the most sensitive species (e.g., beaked whales and harbor porpoise) as well as some of the least sensitive species (e.g., bottlenose dolphins). This is also the only group for which both field behavioral response studies and captive controlled exposure experiments have been conducted, leading to the assessment of both contextually driven responses as well as dose-based responses. This wide range in both exposure situations and individual- and species-sensitivities makes reaching general conclusions difficult. However, it does appear as though exposures in close proximity, with multiple vessels that approach the animal lead to higher-level responses in most odontocete species regardless of received level or behavioral state. In contrast, in more “real-world” exposure situations, with distant sources moving in variable directions, behavioral responses appear to be driven by behavioral state, individual experience, or species-level sensitivities. These responses may also occur more in-line with received level such that the likelihood of a response would increase with increased received levels. However, these “real-world” responses are more likely to be short term, lasting the duration of the exposure or even shorter as the animal assesses the sound and (based on prior experience or contextual cues) determines a threat is unlikely. Therefore, while odontocete behavioral responses to Navy sonar will vary across species, populations, and individuals, long-term consequences or population-level effects will depend on the frequency and duration of the disturbance and resulting behavioral response.

Responses by Specific Odontocete Species

Killer Whales

A close examination of the tag data from the Norwegian killer whales indicated that responses were mediated by behavior, signal frequency, or received sound energy. Killer whales changed their dive behavior during deep foraging dives at the onset of low-frequency active sonar (1-2 kHz, sweeping across frequencies) but did not change their dive behavior if they were deep diving during mid-frequency active sonar (6-7 kHz, sweeping across frequencies). Nor did they change their dive behavior if they were conducting shallow dives at the onset of either type of sonar (Sivle et al., 2012b). Killer whale sighting data from the same region in Norway as the behavioral response study in the 3S Project were used to compare the presence or absence of whales from other years against the period with sonar. The authors found a strong relationship between the presence of whales and the abundance of herring, and only a weak relationship between the whales and sonar activity (Kuningas et al., 2013).

Sperm Whales

The behavioral context and parameters of sonar exposure are important variables in sperm whale behavioral response to sonar as well. While there was no change in foraging (deep dive) behavior during mid-frequency active sonar, sperm whales were more responsive to low frequency active sonar (e.g., reduced dive depth, foraging, and vocalization) (Sivle et al., 2012b). In another study, (Harris et al., 2015; Quick et al., 2017) sperm whales were exposed to low frequency active pulsed active sonar at moderate source levels and high source levels, as well as continuous active sonar at moderate source levels for which the summed energy (SEL) equaled the summed energy of the high source level pulsed active sonar (Isojunno et al., 2020). Foraging behavior did not change during exposures to moderate source level sonar, but non-foraging behavior increased during exposures to high source level sonar and to the continuous active sonar, indicating that the SEL was a better predictor of response than SPL. Other studies also demonstrate that higher SELs reduced sperm whale buzzing (i.e., foraging) (Isojunno et al., 2021). The time of day of the exposure and order effects (e.g., the SEL of the previous exposure) were also important covariates in determining the amount of non-foraging behavior (Isojunno et al., 2020). Curé et al. (2021) also found that sperm whales exposed to continuous and pulsed active sonar were more likely to produce low or medium severity responses with higher cumulative SEL. Specifically, the probability of observing a low severity response increased to 0.5 at approximately 173 dB SEL and observing a medium severity response reached a probability of 0.35 at cumulative SELs between 179 and 189 dB.

One study opportunistically observed sperm whale vocalizations during an eight-day multi-platform naval exercise off the Scotian Shelf of Canada. During long bouts of sonar (various waveforms, both pulsed and continuous) lasting up to 13 consecutive hours (median and maximum SPL = 120 dB and 164 dB), sperm whales substantially reduced how often they produced clicks during sonar, indicating a decrease or cessation in foraging behavior (Stanistreet et al., 2022). Few previous studies have shown sustained changes in sperm whales, but there was an absence of sperm whale clicks for six consecutive days of sonar activity.

Melon-Headed Whales

Melon-headed whales responded to each 6–7 kHz signal with "minor transient silencing" (a brief, non-lasting period of silence), and (in a different oceanographic region) pilot whales had no apparent response (DeRuiter et al., 2013a). In a passive acoustic study using Marine Autonomous Recording Units in the Jacksonville Range Complex, the probability of detecting delphinid vocalizations (whistles, clicks, and buzzes) increased during periods of active sonar use (compared to the period prior to its use), while there was no change in the probability of detecting sperm whale clicks (Charif et al., 2015; HDR EOC, 2012).

Common Dolphins

Durban et al. (2022) observed long-beaked common dolphins via land-based observation platform coupled with a drone and multiple acoustic recorders for the first time. Vocal behavior, group cohesion, group size, and group behavior were observed before, during, and after a simulated mid-frequency sonar exposure. The number of whistles and sub-groups increased during the exposure, but the directivity and speed of the tracked subgroup was less affected.

Pilot Whales

Sonar frequency content and behavioral context are important variables in pilot whale behavioral response to sonar. While there was no change in foraging (deep dive) behavior during mid-frequency active sonar, pilot whales had fewer deep dives during low frequency active sonar (Sivle et al., 2012b). Their behavior at the onset of low frequency active sonar was especially important. If they were deep dive foraging at sonar onset, they were more likely to stop feeding and switch to shallow diving, signifying a switch to travel or rest behavior. If they were shallow diving at low frequency active sonar onset, they would not change dive type and would continue to travel or rest (Sivle et al., 2012b). In another study, pilot whales initially reduced foraging time and increased travel behavior during both low frequency active and mid-frequency active sonar exposures, but foraging increased again during subsequent exposures (Isojunno et al., 2017). This kind of behavioral reaction may indicate habituation to sonar or be driven by prey availability. Pilot whales exposed to a 38 kHz downward-facing echosounder did not change their foraging behavior during exposure periods, but their heading variance increased and fewer deep dives were conducted (Quick et al., 2017).

Diving pilot whales are also sensitive to the received level of sonar (around 170 dB re 1 µPa; Antunes et al., 2014). Cessation of foraging appeared to occur at a lower received level (145–150 dB re 1 µPa) than had been observed previously for avoidance behavior (around 170 dB re 1 µPa; Antunes et al., 2014). Pilot whales reduced breathing rates relative to their diving behavior when low frequency active sonar levels were high (180 dB re 1 µPa), but only on the first sonar exposure. On subsequent exposures their breathing rates increased (Isojunno et al., 2018), indicating a change in response tactic with additional exposures (Isojunno et al., 2018). Other behavioral responses to sonar include the synchronization of pilot whale surfacing's with sonar pulses during one exposure, possibly as a means of mitigating the sound (Wensveen et al., 2015), and pilot whales mimicking the sound of the sonar with their whistles (Alves et al., 2014).

None of the tagged pilot whales near sonar activities in Hawaii demonstrated a large-scale avoidance response as they moved on or near the range; estimated received SPLs varied from 130 to 168 dB re 1 µPa and distances from sonar sources ranged between 3.2 and 94.4 km (Baird et al., 2014; Baird et al., 2017; Baird et al., 2013). However, one pilot whale did have reduced dive rates (from 2.6 dives per hour before to 1.6 dives per hour during) and deeper dives (from a mean of 124 m to 268 m) during a period of sonar exposure. Baird et al. (2016) also tagged four short-finned pilot whales from both the resident island-associated population and from the pelagic population. The core range for the pelagic population was over 20 times larger than for the resident population, leading Baird et al. (2016) to hypothesize that that likelihood of exposure to mid-frequency active sonar, and therefore the potential for response, would be very different between the two populations. These diverse examples demonstrate that responses can be varied, are often context- and behavior-driven, and can be species- and even exposure-specific.

These results demonstrate that the behavioral state and environment of the animal mediates the likelihood of a behavioral response, as do the characteristics (e.g., frequency, energy level) of the sound source itself. The highly flexible activity time budgets observed for pilot whales, with a large amount of time spent resting at the surface, may indicate context-dependency on some behaviors, such as the presence of prey driving periods of foraging. That time may be more easily re-allocated to missed foraging opportunities (Isojunno et al., 2017).

Odontocete Responses to Other Sound Sources

Responses to Killer Whale Playbacks

The anti-predator hypothesis tested on beaked whaled was also assessed with other odontocetes. Scientists played recordings of the same mammal-eating killer whale vocalizations to pilot whales, sperm whales, Risso's dolphins, and even other killer whales, to determine responses by both potential prey and conspecifics (Mobley, 2011; Read et al., 2022; U.S. Department of the Navy, 2011a; Watwood et al., 2012). Results varied, from no response by killer whales to an increase in group size and attraction to the source in pilot whales; rarely does a species have strong aversions as seen in beaked whales (Allen et al., 2014; Tyack et al., 2011), except for the instance of stampeding Risso's dolphins in Southern California (Read et al., 2022). In this case study, when a group of 20 Risso's dolphins were exposed to mammal-eating orca calls (30 sec), they became quiet, swam away at a moderate pace, and at a further distance began to porpoise and swim rapidly away (greater than 12 knots) with quick direction changes, rapid surfacings, and increased synchrony and group cohesion. Two similar sized groups of Risso's followed suite close behind them. They slowed to 5 knots after about 1 hour and 10 km away from their original point of exposure (Read et al., 2022). Changes in foraging duration during killer whale playbacks and mid-frequency active sonar were positively correlated across four species in the 3S Norwegian studies, including long-finned pilot whale and sperm whales, suggesting that tolerance of predation risk may play a role in sensitivity to sonar disturbance (Miller et al., 2022). An alternative explanation to the anti-predator response in odontocete species that respond to sonar is a startle response. Startle responses in bottlenose dolphins occurred at moderate received levels and mid-frequencies, and the relationship between rise time and startle response was more gradual than expected for an odontocete (Gotz et al., 2020).

Responses to Acoustic Harassment and Deterrent Devices

The characteristics of deterrents and the motivation of the animal play a role in the effectiveness of acoustic harassment devices (Schakner & Blumstein, 2013). Deterrents that are strongly aversive or simulate a predator or are otherwise predictive of a threat are more likely to be effective, unless the animal habituates to the signal or learns that there is no true threat associated with the signal. While sperm whales in the Caribbean stopped vocalizing when presented with sounds from nearby acoustic pingers (Watkins & Schevill, 1975), killer whales rapidly habituated to pingers (6.5 kHz, 195 dB re 1 µPa) that were installed to stop them from depredating long lines or aquaculture enclosures. Two groups fled over 700 m away during the first exposure, but they began depredating again after the third and seventh exposures, demonstrating that acoustic harassment devices may be more successful at deterring marine mammals based on their species and context (i.e., prey availability). In some cases, net pingers may even create a “dinner bell effect,” where marine mammals have learned to associate the signal with the availability of prey (Jefferson & Curry, 1996; Schakner & Blumstein, 2013). See Table D.4-9 for a summary of findings from additional studies on these sources.

Table D.4-9: Major Findings from Studies of Acoustic Harassment Devices (AHDs) and Acoustic Deterrent Devices (ADDs) in Other Odontocetes

Species	*Major Finding*	*Supporting Studies*
Sperm whales – wild	Stopped vocalizing when pingers were present.	Watkins and Schevill (1975)
Killer whales – wild	Decreased occurrence when four AHDs deployed on salmon farms. No reduction in occurrence at adjacent location without AHDs. When AHDs removed, whale abundance near farms returned to baseline.	Morton and Symonds (2002)
Killer whales – wild	Habituated to pingers (6.5 kHz, 195 dB re 1 µPa) quickly when next to desired prey species. Fled > 700 m during the first exposure but began depredating again after the third and seventh exposures.	Tixier et al. (2014)
Bottlenose dolphins – captive	Increased surfacing, distance relative to transducer, and reduced clicks when exposed to different deterrent parameters (e.g., pulsed, and continuous tonal signals). Some acclimatization was observed during daily tests, but no habituation was observed over the full duration of the study.	Niu et al. (2012)
Bottlenose dolphins – captive	Different species had different responses to a gillnet pinger (attached to a fishing net and anchor). Bottlenose spent significantly less time in the area when it was present.	Bowles and Anderson (2012)
Bottlenose dolphins – wild	Predated significantly less on commercial fishing catches with pingers nearby (n=2) compared to catches without pingers (n=16).	Ceciarini et al. (2023)
Pacific white-sided dolphins – captive	Approached the gillnet without a pinger but avoided it when the pinger was added.	Bowles and Anderson (2012)

Species	Major Finding	Supporting Studies
Commerson's dolphins – captive	Increased high-energy behavioral responses (e.g., increased swim speed, use of a refuge pool and rate of vocalization) in response to pinger. Did not habituate to pingers but instead sensitized/ demonstrated even stronger aversive behaviors over time.	Bowles and Anderson (2012)
Franciscana dolphins – wild	Avoided active banana pinger (300 ms, 50 – 120 kHz frequency modulated, 145 dB +/- 3 dB at 1 m SL) within 100 m but not at 400 m. No habituation during length of the experiment (64 days).	Paitach et al. (2022)

Notes: % = percent; > = greater than; < = less than; ADD = acoustic deterrent device; AHD = acoustic harassment device; dB = decibel; kHz = kilohertz; km = kilometer; m = meters; rms = root mean square; μPa = micropascal; SL = sound level

D.4.5.2.2 Vessel Disturbance

Behavioral responses to vessels can be caused by multiple factors. The type of vessel, approach, and speed of approach can impact the probability of a negative behavioral response (Ng & Leung, 2003). Even the way research vessels approach or move away from cetaceans can cause varied reactions in group structure and vocal behavior (Guerra et al., 2014). One research group made an effort to distinguish behavioral (e.g., nursing and resting) reactions to vessel noise from vessel presence (Arranz et al., 2021). The short-finned pilot whale mother-calf pairs were approached by the same tour boat with either two quiet electric or noisy petrol engines installed. Approach speed, distance, and vessel features other than engine noise remained the same between the two experimental conditions. While mother pilot whales rested less, and calves nursed less, in response to both types of boat engines compared to control conditions, only the louder petrol engine caused significant impacts (29 percent and 81 percent, respectively) to these behaviors. However, in most field studies the influence of vessel sound exposure cannot be decoupled from the physical presence of a surface vessel, complicating interpretations of the relative contribution of each stimulus to the response. This section will cover both aspects (vessel noise and presence) in publications that specifically aim to target response to noise.

Most odontocetes react neutrally to vessels, although both avoidance and attraction behavior have been observed (Hewitt, 1985; Würsig et al., 1998). Würsig et al. (1998) found that Kogia whales and beaked whales were the most sensitive species to vessels and reacted by avoiding marine mammal survey vessels in 73 percent of sightings, more than any other odontocetes. Avoidance reactions include a decrease in resting behavior or change in travel direction (Bejder et al., 2006a). Incidents of attraction include common, rough-toothed, and bottlenose dolphins bow riding and jumping in the wake of a vessel (Norris & Prescott, 1961; Ritter, 2002; Shane et al., 1986; Würsig et al., 1998). Hudson Bay belugas spent most of their time interacting favorably (e.g., glided under, rubbed against, and swam along) with nearby seasonal tour boats that practiced sustainable whale watching practices (Westdal et al., 2023). A study of vessel reactions by dolphin communities in the eastern tropical Pacific found that populations that were often the target of tuna purse-seine fisheries (spotted, spinner, and common dolphins) show evasive behavior when approached; however, populations that live closer to shore (within 100 NM; coastal spotted and bottlenose dolphins), and are not set on by purse-seine fisheries, tend to be attracted to vessels (Archer et al., 2010). Reactions to vessels may also be context-specific. In some studies, the presence of vessels has been shown to interrupt feeding behavior in delphinids (Meissner et al., 2015; Pirotta et al., 2015b). However, in an important foraging area, bottlenose dolphins (a comparatively less sensitive species of odontocete) may continue to forage and socialize even while constantly exposed to high vessel traffic (Mills et al., 2023).

Smaller vessels (e.g., research and tour boats) generate more noise in higher frequency bands, are more likely to approach odontocetes directly and spend more time near an individual whale. Tour boat activity can cause short-term (Carrera et al., 2008) and longer term or repetitive displacement of dolphins due to chronic vessel noise (Haviland-Howell et al., 2007). Delphinid behavioral states also change in the presence of tourist boats that often approach animals, with travel and resting increasing, foraging and social behavior decreasing, and animals reducing the space between each other (e.g., "group dispersal") (Cecchetti et al., 2017; Clarkson et al., 2020; Kassamali-Fox et al., 2020; Meissner et al., 2015). Most bottlenose dolphin studies on the behavioral reactions to vessel traffic have documented at least short-term changes in behavior, activities, or vocalization patterns when vessels are nearby (Acevedo, 1991; Arcangeli & Crosti, 2009; Berrow & Holmes, 1999; Fumagalli et al., 2018; Gregory & Rowden, 2001; Janik & Thompson, 1996; Lusseau, 2004; Marega et al., 2018; Mattson et al., 2005; Perez-Ortega et al., 2021; Puszka et al., 2021; Scarpaci et al., 2000). Table D.4-10 provides some examples of behavioral responses to different vessel types, with a focus on small recreational vessels and tour boats.

Northern and Southern resident killer whales are sought after by numerous small whale watching vessels in the Pacific Northwest and live in a high traffic area with many different types of vessels. For many years (1998 – 2012) these populations had an average of 20 vessels within 0.5 miles of their location during daytime hours every month (Clark, 2015; Eisenhardt, 2014; Erbe et al., 2014). These vessels had source levels that ranged from 145 to 169 dB re 1 µPa and produced broadband noise up to 96 kHz. Received levels of vessel noise did not decrease with the implementation of new policy on vessel distance. Instead noise levels increased as more and faster moving vessels were introduced (Holt et al., 2017). These noise levels can result in behavioral disturbance (e.g., feeding, nursing, rubbing behavior), interfere with communication, and affect the killer whales' hearing capabilities via masking {Konrad Clarke, 2024 #16751}(Erbe, 2002; Veirs et al., 2015). Factors other than vessel noise that contribute to the severity of killer whales behavioral response to vessels include seasonal data (e.g., year and month), a whale's prior experience with vessels (e.g., age and sex), and the number of other vessels present (Williams et al., 2014a).

Sperm whales generally only react to vessels approaching within several hundred meters. Some individuals are prone to avoidance behavior, such as quick diving (Magalhães et al., 2002; Würsig et al., 1998) or less time spent at the surface (Isojunno & Miller, 2015). When vessels were present, sperm whales were quicker to emit their first click after diving (Richter et al., 2006). Sperm whales have also been observed reducing clicks while a vessel passes by, as well as up to a half hour after the vessel passed (Azzara et al., 2013). It is unknown whether these whales left the area, ceased to click, or surfaced during this period. However, some of the reduction in click detections may be due to masking of the clicks by the vessel noise, particularly during the closest point of approach.

Little information is available on the behavioral impacts of vessel disturbance on beaked whales (Cox et al., 2006), but it seems like most beaked whales react negatively to vessels with abrupt diving and other avoidance maneuvers (Würsig et al., 1998). There is some evidence that suggests beaked whales respond to all anthropogenic noise (including vessel and sonar) at similar sound levels (Aguilar de Soto et al., 2006; Tyack et al., 2011; Tyack, 2009). A vocalizing goose-beaked whale was disrupted from foraging when a large, noisy vessel passed, which suggests that some types of vessel traffic may disturb foraging beaked whales (Aguilar de Soto et al., 2006). Exposure to broadband ship noise (received level of 135 dB re 1 µPa) does not change the duration of whale foraging dives, but may restrict the movement of a group (Pirotta et al., 2012).

Table D.4-10: Examples of Behavioral Responses to Vessels by Odontocetes

Species	*Study*	*Boat type*	*Behavioral Change*				
			Feeding or foraging	*Group dispersal*	*Resting*	*Diving duration*	*Traveling or fleeing*
Common dolphins	Stockin et al. (2008)	Tour	↓		↓		
Bottlenose dolphin	Steckenreuter et al. (2011)	Tour	↓	↓			↑ when approached to 50 m (vs 150 m)
Bottlenose dolphin	Toro et al. (2021)	Tour					↑ (avoid vessel and ↓ surface activity)
Indo-Pacific humpback dolphins	Ng and Leung (2003)	Fishing	↑				
Indo-Pacific humpback dolphins	Ng and Leung (2003)	High-speed				↑ in heavy or oncoming traffic	↑
Killer whales	Kruse (1991); Lusseau et al. (2009); Trites and Bain (2000); Williams et al. (2002a); Williams et al. (2009); Williams et al. (2002b)	Tour	↓ when boats < 100 m				↑ when boats < 100 m
Killer whales (esp. females)	Holt et al. (2021)	Tour	↓ (stop) when boats < 400 m				↑ (start) when boats < 400 m
Pilot whales	Arranz et al. (2021)	Tour	↓ nursing		↓		
Beluga whales	Martin et al. (2023b)	Various[1]				Δ dive behavior	↑ speed (< 13 km) and Δ bearing
Beluga whales	Westdal et al. (2023)	Tour	↓				↓ (↑ interactions with boat < 25 m away)
Harbor porpoises	Frankish et al. (2023)	Large tankers				↑ depth at night	↑ distance during day, especially < 300 m

[1]Various ships = tankers, cargo ships, research vessels, fishing, tug boats
Notes: ↑ = increase; ↓ = decrease; < = less than; Δ = change in; km = kilometer; m = meters

Small dolphins and porpoises are also sensitive to vessel noise. Both finless porpoises (Li et al., 2008) and harbor porpoises (Polacheck & Thorpe, 1990) routinely avoid and swim away from large motorized vessels. A study in the Baltic Sea found that harbor porpoises were more likely to horizontally avoid large commercial ships during the day but vertically avoid them at night (Frankish et al., 2023). Near ships, harbor porpoises respond with fewer clicks (Sairanen, 2014), decreased feeding and behavioral bout durations in general (Akkaya Bas et al., 2017). Specifically, foraging harbor porpoises have fewer prey capture attempts and have disrupted foraging when vessels pass closely and noise levels are higher (Wisniewska et al., 2018). A resident population of harbor porpoise that was regularly near vessel traffic (10 m to 1 km away) had no response in 74 percent of interactions and an avoidance response in 26 percent of interactions. Most avoidance responses were observed in groups of 1 to 2 animals, and were the result of fast-moving or steady plane-hulling motorized vessels (Oakley et al., 2017). Larger groups reacted less often, and few responses were observed to non-motorized or stationary vessels (Oakley et al., 2017). Another study of responses to fast moving vessels found that when the vessels were within 50 m, harbor porpoises had an 80 percent probability of changing their swimming direction, but only a 40 percent probability when vessels were beyond 400 m (Akkaya Bas et al., 2017). A study on harbor porpoise in the Baltic Sea found that porpoises were most likely to avoid close ships (< 300 m), but that 5-10% of the time they would also respond to ships > 2 km away, signifying that were not just attuning to ship presence but ship noise as well (Frankish et al., 2023). Although most vessel noise is constrained to lower frequencies below 1 kHz, at close ranges, vessel noise can extend into mid- and high frequencies (into the tens of kHz) (Hermannsen et al., 2014; Li et al., 2015). These frequencies are what harbor porpoises are likely responding to; the mean M-weighted received SPL threshold for a response at these frequencies is 123 dB re 1 µPa (Dyndo et al., 2015). Hermannsen et al. (2019) estimated that noise in the 16 kHz frequency band resulting from small recreational vessels not equipped with an Automatic Identification System and therefore not included in most vessel noise impact models could be elevated up to 124 dB re 1 µPa and raise ambient levels up to 51 dB; these higher levels were associated with vessel speed and range. These authors determined that the threshold levels found by Dyndo et al. (2015) and Wisniewska et al. (2018) were exceeded by 49 to 85 percent of events with high levels of boat noise, and that recreational vessel noise in the 16 kHz band could cause behavioral responses in harbor porpoises.

Naïve populations of bottlenose dolphins (exposed to lower levels of vessel traffic) had stronger and longer lasting reactions to vessel approaches (Bejder et al., 2006b). Fewer reactions in populations of dolphins regularly subjected to high levels of vessel traffic could be a sign of habituation, or it could be that the more sensitive animals in this population previously abandoned the area of higher human activity.

Odontocetes have been shown to make short-term changes to their vocalizations as an immediate response to vessel noise (see Table D.4-4). For example, bottlenose dolphins in Portuguese waters decrease their call rates and change the frequency parameters of whistles in the presence of boats, while dolphin groups with calves increase their whistle rates when tourist boats are within 200 m and when the boats increase their speed (Guerra et al., 2014). Foraging Lahille's bottlenose dolphins in Brazil increase the duration of their whistles when there is an increase in the speed or number of boats within 250 m; they also increase the frequency parameters of their whistles, especially when group size or calf presence increased. Likewise, modification of multiple vocalization parameters was shown in belugas residing in an area known for high levels of commercial traffic. These animals decreased their call rate, increased certain types of calls, and shifted upward in frequency content in the presence of small vessel noise (Lesage et al., 1999). An increase in the amplitude of vocalizations (Lombard effect) has also been observed when ships were present (Scheifele et al., 2005).

Long-term modifications to vocalizations may be indicative of a learned response to chronic noise, or of a genetic or physiological shift in the populations. This type of change has been observed in killer whales off the northwestern coast of the United States between 1973 and 2003. This population increased the duration of primary calls once a threshold in observed vessel density (e.g., whale watching) was reached, which is suggested as being a long-term response to increased masking noise produced by the vessels (Foote et al., 2004).

The long-term and cumulative implications of vessel noise on odontocetes is largely unknown (National Academies of Sciences Engineering and Medicine, 2017; National Marine Fisheries Service, 2007) although some long-term consequences have been reported (Lusseau & Bejder, 2007). Repeated exposure to acoustic and other anthropogenic stimuli has been studied in several cases, especially as related to vessel traffic and whale watching. Many authors speculate that repeated interruption of foraging behaviors could lead to long-term implications for odontocete populations (Stockin et al., 2008), and in many contexts their localized and coastal home ranges do make them less resilient than mysticetes to this kind of chronic stressor (Southall et al., 2021). The long-term and cumulative implications of ship sound on odontocetes is largely unknown (National Academies of Sciences Engineering and Medicine, 2017; National Marine Fisheries Service, 2007) although some long-term consequences have been reported (Lusseau & Bejder, 2007). Repeated exposure to acoustic and other anthropogenic stimuli has been studied in several cases, especially as related to vessel traffic and whale watching. Many authors speculate that repeated interruption of foraging behaviors could lead to long-term implications for odontocete populations (Stockin et al., 2008), and in many contexts their localized and coastal home ranges do make them less resilient than mysticetes to this kind of chronic stressor (Southall et al., 2021).

Like mysticetes, odontocete responses to vessel noise are varied. Although many odontocete species seem to be more sensitive to vessel presence and noise, these two factors are difficult to tease apart. Some species (e.g., killer whales and porpoises) may be sensitized to vessels and respond at further distances and lower received levels than other delphinids. In contrast, other species (e.g., bottlenose, spotted, spinner, Clymene, and Pacific white sided dolphins) will approach vessels to bow ride, indicating either that these species are less sensitive to vessels or that the behavioral drive to bow ride supersedes any impact of the associated noise (Würsig et al., 1998). With these broad and disparate responses, it is difficult to assess the impacts of vessel noise on odontocetes.

D.4.5.2.3 Aircraft Disturbance

Behavioral responses to aircraft can be caused by multiple factors. It is difficult for researchers and analysts to separate the effects of aircraft noise and aircraft presence; therefore, this section will cover both aspects in publications that specifically aim to target response to noise.

Variable responses to aircraft have been observed in toothed whales, though overall little change in behavior has been observed during flyovers. Some toothed whales dove, slapped the water with their flukes or flippers, or swam away from the direction of the aircraft during overflights; others did not visibly react (Richardson et al., 1995b). Würsig et al. (1998) found that beaked whales were the most sensitive cetacean and reacted by avoiding marine mammal survey aircraft in 89 percent of sightings and at more than twice the rate as Kogia whales, which was the next most reactive of the odontocetes in 39 percent of sightings. These are the same species that were sensitive to vessel traffic.

During standard marine mammal surveys at an altitude of 750 ft., some sperm whales remained on or near the surface the entire time the aircraft was in the vicinity, while others dove immediately or a few minutes after being sighted. Other authors have corroborated the variability in sperm whales' reactions to fixed-wing aircraft or helicopters (Green et al., 1992; Richter et al., 2006; Richter et al., 2003; Smultea et al., 2008; Würsig et al., 1998). Whale watching aircraft (fixed-wing airplanes and helicopters) apparently caused sperm whales to turn more sharply but did not affect blow interval, surface time, time to first click, or the frequency of aerial behavior (Richter et al., 2003).

A group of sperm whales responded to a circling fixed-wing aircraft (altitude of 800 to 1,100 ft.) by moving closer together and forming a defensive fan-shaped semicircle, with their heads facing outward. Several individuals in the group turned on their sides, apparently to look up toward the aircraft (Smultea et al., 2008). Smaller delphinids generally react to overflights either neutrally or with a startle response (Würsig et al., 1998). A change in travel direction was noted in a group of pilot whales as the a fixed-wing aircraft circled while conducting monitoring (HDR, 2011). No changes in group cohesion or orientation behavior were observed for groups of Risso's dolphins, common dolphins, or killer whales when a survey airplane flew at altitudes of 213–610 m, but this may be due to the plane maintaining lateral distances greater than 500 m in all (Smultea & Lomac-MacNair, 2016).

Helicopters may elicit a greater reaction in odontocetes. Beluga whales reacted to helicopter overflights by diving, breaching, changing direction or behavior, and altering breathing patterns to a greater extent than mysticetes in the same area (Patenaude et al., 2002). These reactions increased in frequency as the altitude of the helicopter dropped below 150 m. Sperm whales showed no reaction to a helicopter until they encountered the downdrafts from the rotors (Richardson et al., 1995b).

Much like mysticetes, odontocetes have demonstrated no responses to unmanned aerial systems at altitudes over 30 m. For example, Durban et al. (2015) conducted photogrammetry studies of killer whales using a small helicopter flown 35‒40 m above the animals with no disturbance noted. However, odontocete responses have been reported with use at reduced altitudes. St. Lawrence belugas responded to drones below 23 m with evasive dive responses; their alert surface active reactions (e.g., tail slap) also increased in larger groups or while socializing (Aubin et al., 2023). These impacts may be species-specific, and could be due either to noise or the shadows created by the vehicle (Smith et al., 2016). Bottlenose dolphins responded to a small portion of unmanned aerial vehicles by briefly orienting when the vehicle was relatively close (10–30 m high), but in most cases did not respond at all (Ramos et al., 2018).

D.4.5.2.4 Impulsive Noise

Impulsive signals, particularly at close range, have a rapid rise time and higher instantaneous peak pressure than other signal types, making them more likely to cause startle responses or avoidance responses. However, at long distances the rise time increases as the signal duration lengthens (similar to a "ringing" sound), making the impulsive signal more similar to a non-impulsive signal (Hastie et al., 2019; Martin et al., 2020). Behavioral reactions from explosive sounds are likely to be similar to reactions studied for other impulsive sounds, such as those produced by air guns and impact pile driving. Data on behavioral responses to impulsive sound sources are limited across all marine mammal groups, with only a few studies available for mysticetes and odontocetes. Most data have come from seismic surveys that occur over long durations (e.g., on the order of days to weeks), and typically utilize large multi-air gun arrays that fire repeatedly. While seismic data provide the best available science for assessing behavioral responses to impulsive sounds by marine mammals, it is likely that these responses represent a worst-case scenario compared to responses to explosives used in Navy activities, which would typically consist of single impulses or a cluster of impulses, rather than long-duration, repeated impulses.

Few data are available on odontocete responses to impulsive sound sources, with only a few studies on responses to seismic surveys, pile driving and construction activity available. However, odontocetes appear to be less sensitive to impulsive sound than mysticetes, with responses occurring at much closer distances. This may be due to the predominance of low-frequency sound associated with these sources that propagates long distances and overlaps with the range of best hearing for mysticetes but is below that range for odontocetes. The exception to this is the harbor porpoise, which has been shown to be highly sensitive to most sound sources, avoiding both stationary (e.g., pile driving) and moving (e.g., seismic survey vessels) impulsive sound sources out to approximately 20 km (e.g., Haelters et al., 2014; Pirotta et al., 2014). However, even this response is short term, with porpoises returning to the area within hours after the cessation of the noise.

There are even fewer direct observations of behavioral reactions from marine mammals due to exposure to explosive sounds. Lammers et al. (2017) recorded dolphin detections near naval mine neutralization exercises and found that although the immediate response (within 30 seconds of the explosion) was an increase in whistles relative to the 30 seconds before the explosion, there was a reduction in daytime acoustic activity during the day of and the day after the exercise within 6 km. However, the nighttime activity did not seem to be different than that prior to the exercise, and two days after there appeared to be an increase in daytime acoustic activity, indicating a rapid return to the area by the dolphins (Lammers et al., 2017).

Ferguson et al. (2006) and Miller et al. (2009) tagged and monitored eight sperm whales in the Gulf of Mexico exposed to seismic air gun surveys. Sound sources were from approximately 2 to 7 NM away from the whales, and received levels were as high as 162 dB SPL re 1 µPa (Madsen et al., 2006). The whales showed no horizontal avoidance, however one whale rested at the water's surface for an extended period of time until air guns ceased firing (Miller et al., 2009). While the remaining whales continued to execute foraging dives throughout exposure, tag data suggested there may have been subtle effects of noise on foraging behavior (Miller et al., 2009). Similarly, Weir (2008) observed that seismic air gun surveys along the Angolan coast did not significantly reduce the encounter rate of sperm whales during the 10-month survey period, nor were avoidance behaviors to air gun impulsive sounds observed. In contrast, Atlantic spotted dolphins did show a significant, short-term avoidance response to air gun impulses within approximately 1 km of the source (Weir, 2008). The dolphins were observed at greater distances from the vessel when the air gun was in use, and when the air gun was not in use they readily approached the vessel to bow ride. Kavanagh et al. (2019) also found that toothed whales were more averse to active air guns, as sightings of several species of odontocetes were reduced by 53 and 29 percent during active and inactive phases of seismic surveys, respectively, compared to baseline surveys. Narwhals exposed to air guns in an Arctic fjord were even more sensitive (Heide-Jorgensen et al., 2021). Even though small and large air gun sources reached ambient noise levels around 3 and 10 km (air gun source levels = 231 and 241 dB re 1 µPa at 1 m), respectively, narwhals still changed their swimming direction away from the source and towards shore when seismic vessels were in line of sight over 11 km away. Swimming speed was context-dependent; whales usually increased speed in the presence of vessels but would reduce speed ("freeze") in response to closely approaching air gun pulses. Other behaviors, like feeding, also ceased when the active air gun noise was less than 10 km away, although received SELs were below 130 dB re 1 μPa^2 s for either air gun at this distance. Due to study research methods and criteria, even these long-distance reactions of narwhals may be conservatively estimating narwhals' range to behavioral response.

Captive bottlenose dolphins sometimes vocalized or were reluctant to return to the test station after exposure to single impulses from a seismic water gun (Finneran et al., 2002). When exposed to multiple impulses from a seismic air gun, some dolphins turned their heads away from the sound source just before the impulse, showing that they could anticipate the timing of the impulses and perhaps reduce the received level (Finneran et al., 2015). During construction (including the blasting of old bastions) of a bridge over a waterway commonly used by the Tampa Bay, Florida stock of bottlenose dolphins, the use of the area by females decreased while males displayed high site fidelity and continued using the area, perhaps indicating differential habitat uses between the sexes (Weaver, 2015).

Harbor porpoises seem to have an avoidance response to seismic surveys. A study using aerial surveys and C-PODs (an autonomous recording device that counts odontocete clicks) found that harbor porpoises appeared to leave the area of the survey, and decreased their foraging activity within 5 to 10 km, as evidenced by both a decrease in vocalizations near the survey and an increase in vocalizations at a distance (Pirotta et al., 2014; Thompson et al., 2013a). However, the animals returned within a day after the air gun operation ceased, and the decrease in occurrence over the survey period was small relative to the observed natural seasonal decrease compared to the previous year.

Harbor porpoises have a similar response to pile driving as well. A similar study using C-PODs at two offshore windfarms to examine differences in harbor porpoises presence and foraging activity between baseline (102 to 104 dB) and construction periods (155 to 161 dB) found decreased presence (8 to 17 percent) and foraging (41 to 62 percent) during construction periods. More porpoises were displaced up to 12 km away from pile driving and 4 km from construction vessels (Benhemma-Le Gall et al., 2021). A number of studies also found strong avoidance responses by harbor porpoises out to 20 km during pile driving; however, animals returned to the area after the activity stopped (Brandt et al., 2011; Dähne et al., 2014; Haelters et al., 2014; Thompson et al., 2010; Tougaard et al., 2005; Tougaard et al., 2009). When bubble curtains were deployed around pile driving, the avoidance distance appeared to be reduced to half that distance (12 km), and the response only lasted about five hours rather than a day before the animals returned to the area (Dähne et al., 2017).

However, not all harbor porpoise behavioral response studies ended in habitat displacement. Bergström et al. (2014) found that although there was a high likelihood of acoustic disturbance during wind farm construction (including pile driving), the impact was short term. In another pile driving study, Graham et al. (2019) found that the distance at which behavioral responses were probable decreased over the course of the construction project, suggesting habituation to pile-driving noise in the local harbor porpoise population. When C-PODs were placed near oil and gas platforms and control sites 15 km away, there was a dose-response effect with the lowest amount of porpoise activity closest to the seismic vessel ($SEL_{single\ shot}$ = 155 dB re 1 µPa^{2}s) and then increasing porpoise activity out to 8–12 km, outside of which levels were similar to baseline. Distance to the seismic vessel was a better model predictor of porpoise activity than sound level. Despite these smaller-scale responses, a large-scale response was not detected, and overall porpoise activity in the seismic area was similar to the control stations; this may indicate that the porpoises were moving around the seismic area to avoid the ship, but not leaving the area entirely (Sarnocińska et al., 2020).

According to a 10-year boat-based line-transect survey in an area which included the preconstruction, construction, and postconstruction of offshore wind farm, harbor porpoises were observed throughout the area during all three phases. However, they were not detected within the footprint of the windfarm and were overall less frequent throughout the study area during the construction phase. They returned after the construction was completed at a slightly higher level than in the preconstruction phase. There was no large-scale displacement of harbor porpoises during construction, and their avoidance behavior only occurred out to about 18 km, in contrast to the approximately 25 km avoidance distance found in other windfarm construction and pile driving monitoring efforts.

A five-year study (2015-2020) found that harbor porpoise detections significantly decreased at the beginning of a pile driving project (SEL at 750 m was 160-164 dB re 1 µPa^{2}s) for an oil and gas platform, but detections appeared to return to baseline levels within five months (Todd et al., 2022). The lack of significant trend over years indicated that porpoises did not experience habitat displacement for the entire five-year period. However, it is important to note that the oil and gas platform construction did not take five years, and the type of sources changed over this five-year period.

When exposing a captive harbor porpoise to impact pile driving sounds, Kastelein et al. (2013b) found that above 136 dB re 1 µPa (zero-to-peak) the animal's respiration rates increased, and at higher levels it jumped more frequently. Swim speed, respiration rate, distance from the transducer, and jumping may also increase in response to pile driving sounds, as long as those sounds have higher frequencies present (i.e., above 6 kHz) (Kastelein et al., 2022).

The occurrence of bottlenose dolphins and harbor porpoises over different area and time scales were assessed with and without impact and vibratory pile driving. While there were fewer hours with bottlenose dolphin detections and reduced detection durations within the pile driving area and increased detection durations outside the area, the magnitude of the effects were small, and the reduced harbor porpoise encounter duration was attributed to seasonal changes outside the influence of the pile driving. However, received levels in this area were lower due to propagation effects than in the other areas described above, which may have led to the lack of or reduced response.

Odontocete behavioral responses to impulsive sound sources are likely species- and context-dependent, with most species demonstrating little to no apparent response. Responses might be expected close to a noise source, under specific behavioral conditions such as females with offspring, or for sensitive species such as harbor porpoises.

D.4.5.3 Behavioral Reactions of Pinnipeds

The pinnipeds consist of phocids ("earless" seals) and otariids (sea lions and fur seals), as well as walruses. The below summary will address best available science regarding responses by phocids, followed by otariids. Although not all species are present in the Study Area, information on their responses to acoustic stressors augment the limited knowledge of behavioral responses by pinnipeds.

D.4.5.3.1 Sonar and Other Transducers

Studies of pinniped behavioral responses to sonar and other transducers are limited. Observed responses seem to be mediated by the contextual factors of the exposure, including the characteristics of the signal (e.g., Hastie et al., 2014) and the behavioral state of the animal. However, all studies of pinniped behavioral response to sonars (not including fisheries deterrents) have been conducted in captivity, so application to real-world exposure situations must be done with caution. Based on exposures to other sound sources in the wild (e.g., impulsive sounds and vessels), pinnipeds may only respond strongly to Navy sonar that is near or approaching.

Different responses displayed by captive and wild phocid seals to sound judged to be "unpleasant" or threatening have been reported, including habituation by captive seals (they did not avoid the sound) and avoidance behavior by wild seals (Götz & Janik, 2010). Captive seals received food (reinforcement) during sound playback, while wild seals were exposed opportunistically. These results indicate that motivational state (e.g., reinforcement via food acquisition) can be a factor in whether an animal tolerates or habituates to novel or unpleasant sounds. Another study found that captive hooded seals reacted to 1–7 kHz sonar signals, in part with displacement (i.e., avoidance) to the areas of least SPL, at levels between 160 and 170 dB re 1 µPa (Kvadsheim et al., 2010b); however, the animals adapted to the sound and did not show the same avoidance behavior upon subsequent exposures. Captive harbor seals responded differently to three signals at 25 kHz with different waveform characteristics and duty cycles. The seals responded to the frequency modulated signal at received levels over 137 dB re 1 µPa by hauling out more, swimming faster, and raising their heads or jumping out of the water, but did not respond to the continuous wave or combination signals at any received level (up to 156 dB re 1 µPa) (Kastelein et al., 2015c). Low-frequency signals of the Acoustic Thermometry of Ocean Climate sound source centered at 75 Hz, with received levels between 118 and 137 dB re 1 µPa, were not found to overtly affect elephant seal dives (Costa et al., 2003). However, they did produce subtle effects that varied in direction and degree among the individual seals, again illustrating the equivocal nature of behavioral effects and consequent difficulty in defining and predicting them.

Harbor seals exposed to seal scarers (i.e., acoustic harassment devices used to deter seals from fishing nets or salmon farms) did not respond in any biologically significant way in several studies (Kastelein et al., 2015b; Mikkelsen et al., 2017; Morton & Symonds, 2002), but did demonstrate minor responses by occasionally hauling out at 128–138 dB re 1 µPa (Kastelein et al., 2015b). Pingers have also been used to deter marine mammals from fishing nets. One study exposed species to novel objects, including a fishing net and anchor with line, both with and without a gillnet pinger. Captive harbor seals, California sea lions and Northern elephant seals avoided a fishing net and anchor with line with a gillnet pinger but did not avoid the same net without a pinger (Bowles & Anderson, 2012). In some cases, pingers on nets lead to the “dinner bell effect,” where the pinger becomes an attractant rather than a deterrent (Carretta & Barlow, 2011).

To better understand otariid responses to tactical mid-frequency sonar, captive California sea lions were exposed to mid-frequency sonar at various received levels (125–185 dB re 1 µPa) during a repetitive task (Houser et al., 2013a). Behavioral responses included a refusal to participate, hauling out, an increase in respiration rate, and an increase in the time spent submerged. Young animals (less than two years old) were more likely to respond than older animals. Dose-response curves were developed both including and excluding those young animals. Most responses below 155 dB re 1 µPa were changes in respiration, whereas over 170 dB re 1 µPa more severe responses began to occur (such as hauling out or refusing to participate); many of the most severe responses came from the younger animals. In another study investigating potential deterrent sounds, captive Steller sea lions were exposed to a variety of sounds for two minutes, at a maximum source level of 165 dB re 1 µPa for non-impulsive sounds (Akamatsu et al., 1996). Killer whale vocalizations (whether these were from fish-eating or mammal-eating killer whales is not stated), 1-4 kHz sweeps, and low source level impulses were least effective at causing adults to respond by hauling out, whereas juveniles were more likely to haul out in response to sweeps and low-level impulses. The intermittent pure tone at 8 kHz was most likely to elicit responses in adults and juveniles, although not consistently. The addition of prey items to the test pool greatly reduced the likelihood of hauling out during a sound exposure.

D.4.5.3.2 Vessel Disturbance

Behavioral responses to vessels can be caused my multiple factors. It is difficult for researchers and analysts to separate the effects of vessel noise and vessel presence; therefore, this section will cover both aspects in publications that specifically aim to target response to noise. Pinniped reactions to vessels are variable and reports include a wide spectrum of possibilities including vigilance, avoidance, alerting, and reduced time feeding, resting, or nursing (Martin et al., 2023a; Martin et al., 2022; Mikkelsen et al., 2019; Richardson et al., 1995b). On the opposite end of the spectrum, some pinnipeds demonstrate in-water attraction or a lack of significant reaction when hauled out, suggesting habituation to or tolerance of vessels (Richardson et al., 1995b). Specific case reports in Richardson et al. (1995b) vary based on factors such as routine anthropogenic activity, distance from the vessel, engine type, wind direction, and ongoing subsistence hunting. As with reactions to sound reviewed by Southall et al. (2007), pinniped responses to vessels are affected by the context of the situation and by the animal's experience. Social variables such as animal density and reproductive context may play a role in degree of responsiveness as well. For example, Cape fur seals were less responsive to vessel noise in sites with lower seal abundances compared to a site with a large breeding colony (Martin et al., 2023a).

Increasing numbers of vessels in coastal areas have reduced haul-out time and increase heart rate for harbor seals in certain contexts. The most harbor seal haul outs on Alaskan tidewater glaciers occur during pupping season, and the presence of any vessel reduced this haul out time, with cruise ships and other large vessels having the strongest effect (Blundell & Pendleton, 2015). Another study in Alaska found that hauled out harbor seals were more likely to flush and enter the water when cruise ships approached the ice within 500 m, and were four times more likely to flush when the cruise ship approaches within 100 m (Jansen et al., 2010). Harbor seal heart rates increased when vessels were present during haul out periods and increased further when vessels approached and animals re-entered the water (Karpovich et al., 2015). Harbor seals responded more to vessels passing by haul out sites in areas with less overall vessel activity, and the model best predicting their flushing behavior included the number of boats, type of boats, and distance to boats. More flushing occurred to non-motorized vessels (e.g., kayaks), likely because they tended to occur in groups rather than as single vessels, and tended to pass closer (25–184 m) to the haul out sites than motorized vessels (55–591 m) (Cates & Acevedo-Gutiérrez, 2017).

Other behaviors not associated with haul-out time and flushing are impacted by vessel disturbance as well. Long-term biologgers (DTAGs) were attached to harbor seals and grey seals to opportunistically examine behaviors over several weeks (Mikkelsen et al., 2019). The data showed that seals were exposed to vessel noise between 2.2 and 20.5 percent of their time in water. Potential responses to vessels, coinciding with increasing or peak vessel noise on the tags, included interruption of resting and foraging behaviors. Although there were no behavioral differences between hauled-out wild cape fur seals exposed to low (60-64 dB re 20 µPa RMS SPL), medium (64-70 dB) and high-level (70-80 dB) vessel noise playbacks, mother-pup pairs spent less time nursing (15-to 31 percent) and more time awake (13 to 26 percent), vigilant (7 to 31 percent), and mobile (2to 4 percent) during boat noise conditions compared to control conditions (Martin et al., 2022).

Impact to pinnipeds may differ based on the location or species, as some populations may be more tolerant to vessel disturbance or have a lower degree of overlap with boat traffic. Walrus reaction to vessel noise in the Arctic remains inconclusive (Taylor et al., 2023). Grey seal reactions to increasing vessel traffic off Ireland's coast in association with construction activities suggest that the number of vessels had an indeterminate effect on the seals' presence (Anderwald et al., 2013). Modeling of harbor seals and grey seals in the UK found that they were most likely to overlap with vessel traffic within 50 km of the coast, which included around half of the seals' Special Areas of Conservation (Jones et al. (2017). While there was no evidence of reduced population size in any of these high overlap areas, estimated received levels of shipping noise and maximum daily M-weighted cumulative SEL values ranged from 170 to 189 dB, with the upper confidence intervals of those estimates sometimes exceeding TTS values.

D.4.5.3.3 Aircraft Disturbance

Richardson et al. (1995b) noted that responsiveness to aircraft overflights generally was dependent on the range (altitude and distance) of the aircraft, the abruptness of the associated aircraft sound, and life cycle stage (breeding, molting, etc.). Pinnipeds may startle, orient towards the sound source, increase vigilance, or briefly re-enter the water, but, in general, they are unresponsive to overflights and typically remain hauled out or immediately return to their haul out location (Blackwell et al., 2004; Gjertz & Børset, 1992). Reactions of walruses on land varied in severity and included minor head raising at a distance of 2.5 km, orienting toward, or entering the water at less than 150 m and 1.3 km in altitude, to full flight reactions at horizontal ranges of less than 1 km at altitudes as high as 1,000–1,500 m (Richardson et al., 1995b).

Helicopters are used in studies of several species of seals hauled out and are considered an effective means of observation (Bester et al., 2002; Gjertz & Børset, 1992), although they have been known to elicit behavioral reactions such as fleeing (Hoover, 1988). For California sea lions and Steller sea lions at a rocky haulout off Crescent City in northern California, helicopter approaches to landing sites typically caused the most severe response of diving into the water (National Oceanic and Atmospheric Administration, 2010). Responses were also dependent on the species, with Steller sea lions being more sensitive and California sea lions more tolerant. Depending on the time between subsequent approaches, animals hauled out in between and fewer animals reacted upon subsequent exposures (National Oceanic and Atmospheric Administration, 2010).

Pinnipeds may respond to unmanned aerial systems, especially those flying at low altitudes, due to their possible resemblance to predatorial birds (Smith et al., 2016), which could lead to displacement or flushing behavior {Olson, 2013, `#7568;Stepien, 2024, `#23665}. Responses may also vary by species, age class, behavior, and habituation to other anthropogenic noise, as well as by the approach type, size, model, and source levels of unmanned aerial vehicle used {Pomeroy, 2015, `#10381;Stepien, 2024, `#23665}. Biological context is also important to consider; gestating pinnipeds were much more likely to be disturbed by UAVs {Stepien, 2024, `#21550}. While pinnipeds generally have demonstrated little response to unmanned aerial systems at altitudes over 55 m, as altitude of UAVs decrease, multiple pinniped species oriented towards the vehicle, decreased resting behaviors and increased vigilance, alerting behaviors, displacement and short-term flushing {Sweeney, 2015, `#7569;Moreland, 2015, `#7570;Laborie, 2021, `#17690;Stepien, 2024, `#23665}.

D.4.5.3.4 Impulsive Noise

Pinnipeds may be the least sensitive marine mammal group to noise sources in this document. Some species may be more sensitive than others and are likely to only respond to loud impulsive sound sources at close ranges by startling, jumping into the water when hauled out, or ceasing foraging, but only for brief periods before returning to their previous behavior (e.g., Southall et al., 2007). Pinnipeds may even experience hearing effects before exhibiting a behavioral response (Southall et al., 2007). A review of behavioral reactions by pinnipeds to impulsive noise can be found in Richardson et al. (1995b) and Southall et al. (2007).

Blackwell et al. (2004) observed that ringed seals exhibited little or no reaction to pile-driving noise with mean underwater levels of 157 dB re 1 µPa and in-air levels of 112 dB re 20 µPa, suggesting that the seals had habituated to the noise. On the other hand, harbor seals were displaced from areas surrounding wind farm pile driving (average pile driving duration 6 hours) at estimated received levels between 166 and 178 dB re 1 µPa SPL (peak to peak), with presence returning to baseline within two hours of cessation of pile driving (Russell et al., 2016). Similarly, harbor and grey seals avoided a seismic air gun by rapidly swimming away and ceasing foraging, then returned to normal behavior afterwards (Thompson et al. 1998, cited in Gordon et al., 2003).

Captive California sea lions avoided sounds from an underwater impulsive source at levels of 165 to 170 dB re 1 µPa (Finneran et al., 2003b). However, few responses were observed by New Zealand fur seals to a towed air gun array operating at full power; rather, when responses were observed it seemed to be to the physical presence of the vessel and tow apparatus, and these only occurred when the vessel was within 200 m and sometimes as close as 5 m (Lalas & McConnell, 2016). Captive Steller sea lions were exposed to a variety of tonal, sweep, impulsive and broadband sounds to determine what might work as a deterrent from fishing nets (Akamatsu et al., 1996). An impulsive sound at a source level of 210 dB re 1 µPa at 1 m was more likely to cause both adults and juveniles to haul out and refuse to eat fish presented in a net compared to other exposures. Fewer instances of juvenile haul outs and no adult haul outs were observed in response to the same impulse sound at a source level of 165 dB re 1 µPa, including with and without the food item in the test pool. Steller sea lions exposed to in-air explosive blasts increased their activity levels and often re-entered the water when hauled out (Demarchi et al., 2012). However, these responses were short-lived and, within minutes, the animals had hauled out again, and there were no lasting behavioral impacts in the days following the blasts.

Hastie et al. (2021) studied how the number and severity of avoidance events may be an outcome of marine mammal cognition and risk assessment. Five captive grey seals were given the option to forage in a high- or low-density prey patch while continuously exposed to silence, pile driving or tidal turbine playbacks (148 dB re 1 µPa at 1 m). One prey patch was closer to the speaker, so had a higher received level in experimental exposures. Overall, seals avoided both anthropogenic noise playback conditions with higher received levels when the prey density was limited but would forage successfully and for as long as control conditions when the prey density was higher, demonstrating that noise has the potential to impact seal foraging decisions if the level is high enough. Experimentally, Götz and Janik (2011) tested underwater startle responses to a startling sound (sound with a rapid rise time and a 93 dB sensation level [the level above the animal's hearing threshold at that frequency]) and a non-startling sound (sound with the same level, but with a slower rise time) in wild-captured gray seals. The animals exposed to the startling treatment avoided a known food source, whereas animals exposed to the non-startling treatment did not react or habituated during the exposure period. The results of this study highlight the importance of the characteristics of the acoustic signal in an animal's response of habituation.

D.4.5.3.5 Missile Launch Noise

Launches of missiles and aerial targets (vehicle launches) from land are unlike many other forms of disturbance because of their sudden sound onsets, high peak levels in some cases, and short durations (Cummings, 1993). While data for pinniped reactions to Navy launches are limited to observations at San Nicholas Island (SNI) on the Point Mugu Sea Range (PMSR), there are extensive observations from this site over nearly two decades (Burke, 2017; Holst et al., 2011; Holst & Greene Jr., 2005; Holst & Greene Jr., 2008; Holst & Greene Jr., 2010; Navy, 2021a, 2021b, 2022; Ugoretz, 2014, 2015, 2016; Ugoretz & Greene Jr., 2012). Visual and acoustic monitoring of pinniped responses (including northern elephant seals, California sea lions, and harbor seals) to every launch from SNI was required under these authorizations of launch activity. The results from these monitoring efforts (2001–2022) are summarized in this section. Over twenty years of observations of pinniped behavioral reactions to rocket and missile launches at Vandenberg Space Force Base (VSFB, formerly Vandenberg Air Force Base) are also available

(Force, 2022).The observations at VSFB are consistent with those from SNI, but notable findings from VSFB are detailed below.

Since launches were relatively infrequent, and of such brief duration, it is unlikely that pinnipeds near the SNI launch sites were habituated to launch sounds. The most common type of reaction to airborne noise from missile launches at SNI was a momentary “alert” response. When the animals heard or otherwise detected the launch, they were likely to become alert and interrupt prior activities to pay attention to the launch. For both northern elephant seals and California sea lions, the proportion of animals that moved was significantly related to the closest point of approach of the vehicle or the weighted sound exposure level of the event (based on pinniped in-air M-weighting function from Southall et al. (2007). These relationships were not evident for harbor seals, despite this species being the most susceptible to disturbance (Holst et al., 2011). In cases where animals were displaced from normal activity, the displacement was typically short in duration (5–15 minutes, although some harbor seals left their haulout site until the following low tide when the haulout site was again accessible).

Observations indicated that elephant seals rarely showed more than a momentary alert, even when exposed to noise levels or types that caused nearby harbor seals and California sea lions to react more (this was also the case for northern fur seals at VSFB). Most elephant seals raised their heads briefly upon hearing the launch sounds and then quickly returned to their previous activity pattern (usually sleeping). During some launches, a small proportion of northern elephant seals moved a short distance on the beach or into the water, away from their resting site, but settled within minutes. Because of this, elephant seals were not specifically targeted for launch monitoring after 2010 (75 FR 71672), although in subsequent years they were often in the field of view when monitoring other species.

California sea lions (especially the young animals) exhibited more reaction than elephant seals, and responses varied by individual and age group. Some exhibited brief startle responses and increased vigilance for a short period after each launch. Others, particularly pups that were playing in groups along the margin of haulouts, appeared to react more vigorously. A greater proportion of hauled-out sea lions typically responded or entered the water when launch sounds were louder.

Harbor seals tended to be the most sensitive of the three target species, and during the majority of launches at SNI, most harbor seals left their haulout sites on rocky ledges to enter the water. In some cases, harbor seals returned to their haulout after a short period of time, while in other cases they did not return during the duration of the video-recording period (which sometimes extended up to several hours after a launch). During the day following a launch, harbor seals usually hauled out again at these sites (Holst & Lawson, 2002). The height of the tide following a launch event may have played a significant role in when harbor seals were able to return to a haulout site.

Since with the first MMPA harassment authorizations and analyses of noise impacts related to space shuttle landings and missile launches in the 1980s, there had been a concern over the suggested possibility that a sonic boom or launch-related noise response could cause “stampede-related” injury or mortality 79 FR 32678 (National Marine Fisheries Service, 2014). There were no observations of any such occurrence at SNI and, specifically for the monitored launches at SNI from 2001 to 2022, there were no observed launch-related injuries or deaths (National Marine Fisheries Service, 2019b; Naval Air Warfare Center Weapons Division, 2018). On several occasions, harbor seals and California sea lion adults moved over pups (which can also happen without the presence of an anthropogenic noise) as the animals moved in response to the launches, but the pups did not appear to be injured. On one occasion, a stampede of California sea lions was observed in response to a sonic boom at VSFB. This was thought to have resulted from a from a particularly high amplitude sonic boom and is noted as an isolated incident.

D.4.5.4 Behavioral Reactions of Sea Otters

D.4.5.4.1 Sonar and Other Transducers

There is no research on the effects of sonar on sea otters. A study that exposed two captive Eurasian otters to simulated AHD sounds underwater at 1 kHz and 14 kHz (105-145 dB re 1uPa rms) found that as sound level increased, the number of dives decreased and latency to extract food increased (Stepien et al., 2024). In addition, the severity of behavioral response (leaving the feeder and surfacing) increased, especially during the 1 kHz tonal exposure, which is closer to Eurasian otters' best hearing sensitivity at 4 kHz in-air (Voigt et al., 2019). In the wild, sea otters may show similar reactions to those of pinnipeds which are also amphibious hearers. However, underwater hearing sensitivities are significantly reduced in sea otters when compared to pinnipeds (Ghoul & Reichmuth, 2014a, 2014b), so any reactions may have lower overall severity. Pinnipeds may haul out, swim faster, or increase their respiration rate in response to sonar (Houser et al., 2013a; Kastelein et al., 2015c). Pinnipeds also showed that they may avoid an area temporarily but may habituate to sounds quickly (Kvadsheim et al., 2010a; Kvadsheim et al., 2010b). Deviations from pinniped behavior could be attributed to the fact that sea otters spend approximately 80 percent of their time on the surface of the water (Curland, 1997) with their heads above the surface, which reduces their exposure to underwater sounds. In addition, sea otter dives are energetically costly (i.e., requiring twice the metabolic energy that phocid seals need to dive). As a result, sea otters may not dive or travel far in response to disturbance, as they already require long periods of rest at the surface to counterbalance the high metabolic cost of foraging at sea (Yeates et al., 2007). Sea otters may also habituate to sonar signals. However, sea otters live too far inshore to likely be exposed to or impacted by Navy sonar or other transducers, and live out of the area of pierside activity.

D.4.5.4.2 Vessel Disturbance

Sea otters that live far inshore and may be exposed to noise from recreational boats and commercial and military ships transiting in and out of port areas. Sea otters have similar in-air hearing sensitivities as pinnipeds (Miksis-Olds et al., 2007; Nowacek et al., 2004b), and may react in a similar fashion when approached by vessels. However, underwater hearing sensitivities are significantly reduced compared to pinnipeds (Ghoul & Reichmuth, 2014a, 2014b). While reactions to underwater vessel noise may occur, they will have lower overall severity to those of pinnipeds. Sea otters in Monterey, CA that were living in areas of disturbance from human activity such as recreational boating spent more time engaged in travel than resting (Curland, 1997). Sea otters in undisturbed areas spent 5 percent of their time travelling; otters in areas of disturbance due to vessels were shown to spend 13 percent of their time travelling (Curland, 1997). While this may not appear to be a large change in behavior, sea otter dives are very costly and require twice the metabolic energy that phocid seals need to dive; therefore sea otters may not dive or travel far in response to disturbance, as they already require long periods of rest at the surface to counterbalance the high cost of foraging at sea (Yeates et al., 2007). For example, when a single air gun vessel passed a large raft of otters, several otters were mildly alarmed (e.g., rolled over on their sides or bellies and looked intently at the vessel as it approached) but did not leave the raft. However, they reacted to the vessel every time it passed, even though the air gun was only operational for two of the four passes. This indicates that otters were either responding to the loud airborne sounds of the boat engines and compressor, or to the close approach of the vessel itself, rather than the seismic sounds (Reidman, 1983). However, sea otters may habituate quickly. Even when purposefully harassed in an effort to cause a behavioral response, sea otters generally moved only a short distance (100 to 200 m) before resuming normal activity, and nearby boats, nets, and floating oil containment booms were sometimes an attractant (Davis et al., 1988). Although Barrett (2019) found that sea otters have a high metabolic rate and are at risk of increased energetic costs when disturbed, there was less than a 10 percent chance of disturbance when small vessels were more 54 m away from sea otters.

D.4.5.4.3 Aircraft Disturbance

Sea otters spend approximately 80 percent of their time on the surface of the water (Curland, 1997) with their heads above the surface, and will most likely be exposed to noise from aircraft. Recordings of underwater noise produced by helicopter overflights did not appear to affect sea otter foraging behavior, foraging success, or daily activity patterns when projected underwater 1–1.5 km from a group of otters in Lobos Cove (Reidman, 1983). Sea otters have similar in-air hearing sensitivities as pinnipeds (Ghoul & Reichmuth, 2014a, 2014b), and may react in a similar fashion when exposed to aircraft noise. Pinnipeds in general are unresponsive but may react depending on the altitude of the aircraft or the abruptness of the associated sound (Richardson et al., 1995b), with reactions ranging from unresponsiveness to flushing into the water location (Blackwell et al., 2004; Gjertz & Børset, 1992). Sea otters may dive below the surface of the water or flush into the water to avoid aircraft noise. However, sea otter dives are very costly and require twice the metabolic energy that phocid seals need to dive; therefore sea otters may not dive or travel so readily in response to disturbance, as they already require long periods of rest at the surface to counterbalance the high cost of foraging at sea (Yeates et al., 2007). So far, there has been no evidence that any aircraft has had adverse effects on a well-monitored translocated colony of sea otters at San Nicolas Island, which has a landing field operated by the U.S. Navy (U.S. Fish and Wildlife Service, 2012, 2015).

D.4.5.4.4 Impulsive Noise

There are few available studies on responses of sea otters to impulsive sounds. A playback study of multiple and single air guns had no significant impact on sea otters in California. During the multiple air gun exposures, otters rested 1 percent more and foraged 1 percent less. They were successful at obtaining prey during 84 percent of their foraging dives when the air gun vessel was 50 NM away, and the success rate only decreased by 5 percent when the multiple air gun vessel moved closer (0.5 NM away). Overall, foraging and dive behaviors remained undisturbed, as did the density and distribution of sea otters in the area. This study caveats that the data were collected under rough weather conditions which could have affected the otters' perception of the seismic sounds. In addition, otters kept close to shore in relatively sheltered coves (Reidman, 1983).

During the single air gun experiment, the air gun ship approached a raft of otters (at a minimum of 730 m), and several otters were mildly alarmed (e.g., rolled over on their sides or bellies and looked intently at the vessel as it approached) but did not leave the raft. Of the four times the vessel passed the group of otters, the air gun was operational during only two of the transects. However, the otters reacted to the vessel every time it passed, indicating that otters were either responding to the loud airborne sounds of the boat engines and compressor, or to the close approach of the vessel itself, rather than the seismic sounds (Reidman, 1983).

In a follow-up study, Riedman (1984) monitored sea otter reactions to drilling platform sounds and air gun firing projected from a source vessel 0.9 to 1.6 km away from groups of sea otters. No behavioral reactions or movements were observed in 14 days of observations with 15–38 individual sea otters present on any given day. Sound pressure levels from the air gun were reported as 166 dB re 1 µPa at

1.1 km, which means that two otters may have been subjected to levels greater than this at ranges of 900 m on the one day the pair foraged closer to the air gun ship for one hour. Most of the otters would have been subjected to just under this level, since the majority of otters foraged 1.3–1.6 m away from the sound sources, and propagation loss due to distance and the kelp environment needs to be considered. In a survey of the local coastline, no change in numbers of sea otters was evident between just prior to the sound stimuli and on day 10 of the emissions. No changes in feeding dive times or feeding success was seen during the study either.

When conducting impact and vibratory pile driving for the Parsons Slough estuarine restoration, the Elkhorn Slough National Estuarine Research Reserve (2011) recorded the abundance and behavior of sea otters in the area. Disturbances within 30 m of the pile driving site included otters raising their heads, swimming away without startling, or startle diving. Usually only single adult males with an established territory that included the construction site traveled within 30 m. Otters further away (> 180 m) were observed swimming away with startling, including mother-pup pairs. However, sea otter behavioral disturbances 30–180 m away from the pile driving site were difficult to tease apart from the impacts of pedestrian vessels and other construction activities.

Sea otters spend approximately 80 percent of their time on the surface of the water (Curland, 1997) with their heads above the surface, which reduces their exposure to underwater sounds. They require long periods of undisturbed rest at the surface to counterbalance high metabolic costs associated with forging at sea (Yeates et al., 2007). If reactions to Navy impulsive noise were to occur, they may be similar to those of pinnipeds, which show temporary avoidance responses or cessation of foraging behavior (Gordon et al., 2003; Thompson et al., 1998). However, underwater hearing sensitivities are significantly reduced in sea otters when compared to pinnipeds (Ghoul & Reichmuth, 2014a, 2014b), so reactions may not be as strong, if they occur at all.

D.4.6 Physiological Response

The growing field of conservation physiology relies in part on the ability to monitor stress hormones in populations of animals, particularly those that are threatened or endangered. Physiological stress is an adaptive process that helps an animal cope with changing conditions. The ability to make predictions from stress hormones about impacts on individuals and populations exposed to various forms of stressors, natural and human-caused, relies on understanding the linkages between changes in stress hormones and resulting physiological impacts. Currently, the sound characteristics that correlate with specific stress responses in marine mammals are poorly understood, as are the ultimate consequences of these changes. Navy-funded efforts have improved the understanding of and the ability to predict how stressors ultimately affect marine mammal populations (e.g., King et al., 2015; New et al., 2013a; Pirotta et al., 2015a; Pirotta et al., 2022b). This includes not only determining how and to what degree various types of anthropogenic sound cause stress in marine mammals, but what factors can mitigate those responses. Factors potentially affecting an animal’s response to a stressor include the mammal’s life history, sex, age, reproductive status, overall physiological and behavioral plasticity, and whether they are naïve or experienced with the sound (e.g., prior experience with a stressor may result in a reduced response due to habituation)(Finneran & Branstetter, 2013; St. Aubin & Dierauf, 2001). Because there are many unknowns regarding the occurrence of acoustically induced stress responses in marine mammals, any physiological response (e.g., hearing loss or injury) or significant behavioral response is assumed to be associated with a stress response.

Marine mammals naturally experience stressors within their environment and as part of their life histories. Changing weather and ocean conditions, exposure to disease and naturally occurring toxins, lack of prey availability, and interactions with predators all contribute to the stress a marine mammal experiences (Atkinson et al., 2015). Breeding cycles, periods of fasting, social interactions with members of the same species, and molting (for pinnipeds) are also stressors, although they are natural components of an animal's life history. Anthropogenic activities have the potential to provide additional stressors beyond those that occur naturally (Fair et al., 2014; Meissner et al., 2015; Rolland et al., 2012). Anthropogenic stressors potentially include such things as fishery interactions, pollution, tourism, and ocean noise.

Relatively little information exists on the linkage between anthropogenic sound exposure and stress in marine mammals, and even less information exists on the ultimate consequences of sound-induced stress responses (either acute or chronic). Most studies to date have focused on acute responses to sound either by measuring catecholamines or heart rate as an assumed proxy for an acute stress response.

D.4.6.1 Heart Rate Response

Increases in heart rate were observed in captive bottlenose dolphins to which known calls of other dolphins were played, although no increase in heart rate was observed when background tank noise was played back (Miksis et al., 2001). Unfortunately, it cannot be determined whether the increase in heart rate was due to stress or social factors, such as expectation of an encounter with a known conspecific. Similarly, a young captive beluga's heart rate increased during exposure to noise, with increases dependent upon the frequency band of noise and duration of exposure, and with a sharp decrease to normal or below normal levels upon cessation of the exposure (Lyamin et al., 2011). Spectral analysis of heart rate variability corroborated direct measures of heart rate (Bakhchina et al., 2017). This response might have been in part due to the conditions during testing, the young age of the animal, and the novelty of the exposure; a year later the exposure was repeated at a slightly higher received level and there was no heart rate response, indicating the beluga whale had potentially habituated to the noise exposure.

Kvadsheim et al. (2010a) measured the heart rate of captive hooded seals during exposure to sonar signals and found an increase in the heart rate of the seals during exposure periods versus control periods when the animals were at the surface. When the animals dove, the normal dive-related heart rate decrease was not impacted by the sonar exposure. Similarly, Thompson et al. (1998) observed a rapid but short-lived decrease in heart rates in wild harbor and grey seals exposed to seismic air guns (cited in Gordon et al., 2003).

Two captive harbor porpoises showed significant bradycardia (reduced heart rate), below that which occurs with diving, when they were exposed to pinger-like sounds with frequencies between 100-140 kHz (Teilmann et al., 2006). The bradycardia was found only in the early noise exposures and the porpoises acclimated quickly across successive noise exposures. Elmegaard et al. (2021) also found that initial exposures to sonar sweeps produced bradycardia but did not elicit a startle response in captive harbor porpoises. As with Teilmann et al. (2006), the cardiac response disappeared over several repeat exposures suggesting rapid acclimation to the noise. In the same animals, 40-kHz noise pulses induced startle responses but without a change in heart rate. Bakkeren et al. (2023) found no change in the heart rate of a harbor porpoise during exposure to masking noise (1/3rd octave band noise, centered frequency of 125 kHz, maximum received level of 125 dB re 1 μPa) during an echolocation task but showed significant bradycardia while blindfolded for the same task. The authors attributed the change in heart rate to sensory deprivation, although no strong conclusions about acoustic masking could be made since the animal was still able to perform the echolocation task in the presence of the masking noise.

Williams et al. (2022) observed periods of increased heart rate variability in narwhals during seismic air gun impulse exposure, but profound bradycardia was not noted. Conversely, Williams et al. (2017) found that a profound bradycardia persisted in narwhals, even though exercise effort increased dramatically as part of their escape response following release from capture and handling.

Limited evidence across several different species suggests that increased heart rate might occur as part of the acute stress response of marine mammals that are at the surface. However, the decreased heart rate typical of diving marine mammals can be enhanced in response to an acute stressor, suggesting that the context of the exposure is critical to understanding the cardiac response. Furthermore, in instances where a cardiac response was noted, there appears to be rapid habituation when repeat exposures occur. Additional research is required to understand the interaction of dive bradycardia, noise-induced cardiac responses, and the role of habituation in marine mammals.

D.4.6.2 Stress Hormone and Immune Response

What is known about the function of the various stress hormones is based largely upon observations of the stress response in terrestrial mammals. The endocrine response of marine mammals to stress may not be the same as that of terrestrial mammals because of the selective pressures marine mammals faced during their evolution in an ocean environment (Atkinson et al., 2015). For example, due to the necessity of breath-holding while diving and foraging at depth, the physiological role of epinephrine and norepinephrine (the catecholamines) might be different in marine versus other mammals.

Catecholamines increase during breath-hold diving in seals, co-occurring with a reduction in heart rate, peripheral vasoconstriction (constriction of blood vessels), and an increased reliance on anaerobic metabolism during extended dives (Hance et al., 1982; Hochachka et al., 1995; Hurford et al., 1996); the catecholamine increase is not associated with increased heart rate, glycemic release, and increased oxygen consumption typical of terrestrial mammals. Captive belugas demonstrated no catecholamine response to the playback of oil drilling sounds (Thomas et al., 1990b) but showed a small but statistically significant increase in catecholamines following exposure to impulsive sounds produced from a seismic water gun (Romano et al., 2004). A captive bottlenose dolphin exposed to the same sounds did not demonstrate a catecholamine response, but did demonstrate a statistically significant elevation in aldosterone (Romano et al., 2004), however, the increase was within the normal daily variation observed in this species (St. Aubin et al., 1996) and was likely of little biological significance. Aldosterone has been speculated to not only contribute to electrolyte balance, but possibly also the maintenance of blood pressure during periods of vasoconstriction (Houser et al., 2011). In marine mammals, aldosterone is thought to play a role in mediating stress (St. Aubin & Dierauf, 2001; St. Aubin & Geraci, 1989).

Yang et al. (2021) measured cortisol concentrations in two captive bottlenose dolphins and found significantly higher concentrations after exposure to 140 dB re 1 μPa impulsive noise playbacks. Two out of six tested indicators of immune system function underwent acoustic dose-dependent changes, suggesting that repeated exposures or sustained stress response to impulsive sounds may increase an affected individual’s susceptibility to pathogens. Unfortunately, absolute values of cortisol were not provided, and it is not possible from the study to tell if cortisol rose to problematic levels (e.g., see normal variation and changes due to handling in Houser et al. (2021) and Champagne et al. (2018)). Exposing dolphins to a different acoustic stressor yielded contrasting results. Houser et al. (2020) measured cortisol and epinephrine obtained from 30 captive bottlenose dolphins exposed to simulated U.S. Navy mid-frequency sonar and found no correlation between SPL and stress hormone levels, even though sound exposures were as high as 185 dB re 1 µPa. In the same experiment (Houser et al., 2013b), behavioral responses were shown to increase in severity with increasing received SPLs. These results suggest that behavioral reactions to sonar signals are not necessarily indicative of a hormonal stress response.

Whereas a limited amount of work has addressed the potential for acute sound exposures to produce a stress response, almost nothing is known about how chronic exposure to acoustic stressors affects stress hormones in marine mammals, particularly as it relates to survival or reproduction. In what is probably the only study of chronic noise exposure in marine mammals associating changes in a stress hormone with changes in anthropogenic noise, Rolland et al. (2012) compared the levels of cortisol metabolites in North Atlantic right whale feces collected before and after September 11, 2001. Following the events of September 11, shipping was significantly reduced in the region where fecal collections were made, and regional ocean background noise declined. Fecal cortisol metabolites significantly decreased during the period of reduced ship traffic and ocean noise (Rolland et al., 2012). Rolland et al. (2017) also compared acute (death by ship strike) to chronic (entanglement or live stranding) stressors in North Atlantic right whales and found that whales subject to chronic stressors had higher levels of glucocorticoid stress hormones (cortisol and corticosterone) than either healthy whales or those killed by ships. It was presumed that whales subjected to acute stress may have died too quickly for increases in fecal glucocorticoids to be detected.

Considerably more work has been conducted in an attempt to determine the potential effect of vessel disturbance on smaller cetaceans, particularly killer whales (Bain, 2002; Erbe, 2002; Lusseau, 2006; Noren et al., 2009; Pirotta et al., 2015b; Read et al., 2014; Rolland et al., 2012; Williams et al., 2009; Williams et al., 2014a; Williams et al., 2014b; Williams et al., 2006b). Most of these efforts focused primarily on estimates of metabolic costs associated with altered behavior or inferred consequences of boat presence and noise but did not directly measure stress hormones. However, Ayres et al. (2012) investigated Southern Resident killer whale fecal thyroid hormone and cortisol metabolites to assess two potential threats to the species' recovery: lack of prey (salmon) and impacts from exposure to the physical presence of vessel traffic (but without measuring vessel traffic noise). Ayres et al. (2012) concluded from these stress hormone measures that the lack of prey overshadowed any population-level physiological impacts on Southern Resident killer whales due to vessel traffic. Lemos et al. (2022) investigated the potential for vessel traffic to affect gray whales. By assessing gray whale fecal cortisol metabolites across years in which vessel traffic was variable, Lemos et al. (2022) found a direct relationship between the presence/density of vessel traffic and fecal cortisol metabolite levels. Unfortunately, no direct noise exposure measurements were made on any individual making it impossible to tell if other natural and anthropogenic factors could also be related to the results. Collectively, these studies indicate the difficulty in determining which factors are primarily influence the secretion of stress hormones, including the separate and additive effects of vessel presence and vessel noise. While vessel presence could contribute to the variation in fecal cortisol metabolites in North Atlantic right whales and gray whales, there are other potential influences on fecal hormone metabolites, so it is difficult to establish a direct link between ocean noise and fecal hormone metabolites.

D.4.7 Direct Injury

D.4.7.1 Injury due to Sonar

An object exposed to its resonant frequency will tend to amplify its vibration at that frequency, a phenomenon called acoustic resonance. Acoustic resonance has been proposed as a mechanism by which a sonar or sources with similar operating characteristics could damage tissues of marine mammals. In 2002, NMFS convened a panel of government and private scientists to investigate the potential for acoustic resonance to occur in marine mammals (National Oceanic and Atmospheric Administration, 2002). They modeled and evaluated the likelihood that Navy mid-frequency sonar caused resonance effects in beaked whales that eventually led to their stranding. The conclusion of the group was that resonance in air-filled structures did not likely cause the Bahamas stranding in 2000. The frequency at which resonance was predicted to occur in the animals' lungs was 50 Hz, well below the frequencies used by the mid-frequency sonar systems associated with the Bahamas event. Furthermore, air cavity vibrations, even at resonant frequencies, were not considered to be of sufficient amplitude to cause tissue damage, even under the unrealistic scenario in which air volumes would be undamped (unrestrained) by surrounding tissues and the amplitude of the resonant response would be greatest. These same conclusions would apply to other training activities involving acoustic sources. Therefore, the Action Proponents conclude that acoustic resonance would not occur under real training conditions. The potential impact of acoustic resonance is not considered further in this analysis.

D.4.7.1.1 Acoustically Induced Bubble Formation

A suggested cause of injury to marine mammals is rectified diffusion (Crum & Mao, 1996), the process of increasing the size of a microscopic gas bubble by exposing it to a sound field. The process is dependent upon several factors including the SPL and duration. Under this hypothesis, microscopic bubbles assumed to exist in the tissues of marine mammals may experience one of three things: (1) bubbles grow to the extent they become emboli or cause localized tissue trauma, (2) bubbles develop to the extent that a complement immune response is triggered or the nervous tissue is subjected to enough localized pressure that pain or dysfunction occurs (a stress response without injury), or (3) the bubbles are cleared by the lung without negative consequence to the animal.

Rectified diffusion is facilitated if the environment in which the ensonified bubbles exist is supersaturated with gas. As discussed above, repetitive diving by marine mammals can cause the blood and some tissues to become supersaturated (Ridgway & Howard, 1979). The dive patterns of some marine mammals (e.g., beaked whales) are predicted to induce greater supersaturation (Houser et al., 2001b). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pulses would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested: stable microbubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of supersaturated tissues. In such a scenario, the marine mammal would need to be in a gas-supersaturated state for a long enough time for bubbles to become a problematic size. The phenomena of bubble growth due to a destabilizing exposure was shown by Crum et al. (2005) by exposing highly supersaturated ex vivo bovine tissues to a 37 kHz source at 214 dB re 1 µPa. Although bubble growth occurred under the extreme conditions created for the study, these conditions would not exist in the wild because the levels of tissue supersaturation in the study (as high as 400 to 700 percent) are substantially higher than model predictions for marine mammals (Fahlman et al., 2009; Fahlman et al., 2014; Houser et al., 2001b; Saunders et al., 2008), and such high exposure levels would only occur in very close proximity to the most powerful sonars. For these reasons, it is improbable that this mechanism is responsible for stranding events or traumas associated with beaked whale strandings.

There has been considerable disagreement among scientists as to the likelihood of this phenomenon (Evans & Miller, 2003; Piantadosi & Thalmann, 2004). Although it has been argued that traumas from beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Fernandez et al., 2005; Jepson et al., 2003), nitrogen bubble formation as the cause of the traumas has not been verified. The presence of bubbles postmortem, particularly after decompression, is not necessarily indicative of bubble pathology (Bernaldo de Quiros et al., 2012; Bernaldo de Quiros et al., 2013a; Bernaldo de Quiros et al., 2013b; Dennison et al., 2012; Moore et al., 2009), and other mechanisms by which bubble emboli might occur once animals are rapidly stranded (e.g., cardiovascular collapse preventing tissue off-gassing) have not been ruled out (Houser et al., 2009).

D.4.7.1.2 Behaviorally Mediated Injury

Marine mammals mitigate nitrogen gas accumulation in their blood and other tissues, which is caused by gas exchange from the lungs under conditions of increased hydrostatic pressure during diving, through anatomical, behavioral, and physiological adaptations (Hooker et al., 2012).

Although not an injury caused by the interaction of sound with tissues, variations in marine mammal diving behavior or avoidance responses in response to sound exposure have been hypothesized to result in the off-gassing of nitrogen super-saturated tissues, possibly to the point of deleterious vascular and tissue bubble formation (Hooker et al., 2012; Jepson et al., 2003; Saunders et al., 2008) with resulting symptoms similar to decompression sickness (also known as “the bends”).

Whether marine mammals can produce deleterious gas emboli has been under debate in the scientific community (Hooker et al., 2012; Saunders et al., 2008), although various lines of evidence have been presented in support of the phenomenon. Some of these postulations are described below.

- Analyses of bycaught animals demonstrated that nitrogen bubble formation occurs in drowned animals when they are brought to the surface (Bernaldo de Quiros et al., 2013b; Moore et al., 2009). Since gas exchange with the lungs no longer occurs once drowned, tissues become supersaturated with nitrogen due to the reduction in hydrostatic pressure near the surface. This demonstrates that the phenomenon of bubble formation is at least physically possible.
- The presence of osteonecrosis (bone death due to reduced blood flow) in deep-diving sperm whales has been offered as evidence of impacts due to chronic nitrogen supersaturation and a lifetime of decompression insults (Moore & Early, 2004).
- Dennison et al. (2012) investigated dolphins stranded in 2009–2010. Using ultrasound, they identified gas bubbles in kidneys of 21 of the 22 live-stranded dolphins and in the liver of two of the 22. The authors postulated that stranded animals were unable to recompress by diving, and thus retained bubbles that would have otherwise re-absorbed in animals that continued to dive. However, the researchers concluded that the minor bubble formation observed could be tolerated since most stranded dolphins released did not re-strand.
- A fat embolic syndrome (out-of-place fat particles, typically in the bloodstream) was identified by Fernandez et al. (2005) coincident with the identification of bubble emboli in stranded

beaked whales. The fat embolic syndrome was the first pathology of this type identified in marine mammals and was thought to possibly arise from the formation of bubbles in fat bodies, which subsequently resulted in the release of fat emboli into the blood stream.

- Findings of gas and fat emboli in a few stranded Risso's dolphin, and in which sonar exposure was ruled out as a cause of stranding, suggested that other factors, in this case struggling with a prey item, might cause significant variations in dive behavior such that emboli formation could occur (Fernandez et al., 2017).

Only one study has attempted to find vascular bubbles in a freely diving marine mammal (Houser et al., 2009). In that study, no vascular bubbles were imaged by ultrasound in a bottlenose dolphin that repeatedly dove to a 100 m depth and maintained a dive profile meant to maximize nitrogen gas uptake. Thus, although lines of evidence suggest that marine mammals manage excessive nitrogen gas loads, most of the evidence for the formation of bubble and fat emboli come from stranded animals in which physiological compromise due to the stranding event is a potential confounding factor. To validate decompression sickness observations in certain stranded cetaceans found coincident with naval activities, a study used rabbits as an experimental pathological model and found that rabbit mortalities during or immediately following decompression showed systematically distributed gas bubbles (microscopic and macroscopic), as well as emphysema and hemorrhages in multiple organs, similar to observations in the stranded cetacean mortalities (Velazquez-Wallraf et al., 2021). Similar findings were not found in almost half the rabbits that survived at least one hour after decompression, revealing individual variation has an essential role in this condition.

Researchers have examined how dive behavior affects tissue supersaturation conditions that could put an animal at risk of gas bubble embolism. An early hypothesis was that if exposure to a startling sound elicits a rapid ascent to the surface, tissue gas saturation sufficient for the evolution of nitrogen bubbles might result (Fernandez et al., 2005; Jepson et al., 2003). However, modeling suggested that even unrealistically rapid rates of ascent from normal dive behaviors are unlikely to result in supersaturation to the extent that bubble formation would be expected in beaked whales (Zimmer & Tyack, 2007). Instead, emboli observed in animals exposed to mid-frequency active sonar (Fernandez et al., 2005; Jepson et al., 2003) could stem from a behavioral response that involves repeated dives, shallower than the depth of lung collapse (Aguilar de Soto et al., 2006; Hooker et al., 2012; Tyack et al., 2006; Zimmer & Tyack, 2007). Longer times spent diving at mid-depths above lung collapse would allow gas exchange from the lungs to continue under high hydrostatic pressure conditions, increasing potential for supersaturation; below the depth of lung collapse, gas exchange from the lungs to the blood would likely not occur (Costidis & Rommel, 2016; Fahlman et al., 2014). To estimate risk of decompression sickness, Kvadsheim et al. (2012) modeled gas exchange in the tissues of sperm, pilot, killer, and beaked whales based on actual dive behavior during exposure to sonar in the wild. Results predicted that venous supersaturation would be within the normal range for these species, which would presumably have naturally higher levels of nitrogen gas loading. Nevertheless, deep-diving whales, such as beaked whales, have also been predicted to have higher nitrogen gas loads in body tissues for certain modeled changes in dive behavior, which might make them more susceptible to decompression sickness (Fahlman et al., 2014; Fernandez et al., 2005; Hooker et al., 2012; Jepson et al., 2003). Bernaldo de Quirós et al. (2019) summarized discussions from a 2017 workshop on potential sonar impacts on beaked whales, suggesting that the effect of mid-frequency active sonar on beaked whales varies among individuals or populations and that predisposing conditions such as previous exposure to sonar and individual health risk factors may contribute to individual outcomes (such as decompression sickness) as well.

Modeling has suggested that the long, deep dives performed regularly by beaked whales over a lifetime could result in the saturation of long-halftime tissues (i.e., tissues that take longer to give off nitrogen, e.g., fat and bone lipid) to the point that they are supersaturated when the animals are at the surface (Fahlman et al., 2014; Hooker et al., 2009; Saunders et al., 2008). Proposed adaptations for prevention of bubble formation under conditions of persistent tissue saturation have been suggested (Fahlman et al., 2006; Hooker et al., 2009), and because of the time it takes for tissue offloading, it is feasible that long-halftime tissues are not a concern for decompression insults under normal ventilation or dive (recompression) conditions. However, for beaked whale strandings associated with sonar use, one proposed hypothesis is that observed bubble formation may be caused by compromised blood flow due to stranding-related cardiovascular collapse. This would reduce the ability to remove nitrogen from tissues following rapid sonar-induced stranding and could preclude typical management of nitrogen in supersaturated, long-halftime tissues (Houser et al., 2009).

Predictive modeling conducted to date has been performed with many unknowns about the respiratory physiology of deep-diving breath-hold animals. For example, Denk et al. (2020) found intra-species differences in the compliance of tracheobronchial structures of post-mortem cetaceans and pinnipeds under diving hydrostatic pressures, which would affect depth of alveolar collapse. Although, as hypothesized by Garcia Parraga et al. (2018) and reviewed in (Fahlman et al., 2021), mechanisms may exist that allow marine mammals to create a pulmonary shunt without the need for hydrostatic pressure-induced lung collapse, i.e., by varying perfusion to the lung independent of lung collapse and degree of ventilation. If such a mechanism exists, then assumptions in prior gas models require reconsideration, the degree of nitrogen gas accumulation associated with dive profiles needs to be re-evaluated, and behavioral responses potentially leading to a destabilization of the relationship between pulmonary ventilation and perfusion should be considered. Costidis and Rommel (2016) suggested that gas exchange may continue to occur across the tissues of air-filled sinuses in deep diving odontocetes below the depth of lung collapse if hydrostatic pressures are high enough to drive gas exchange across into non-capillary veins.

If feasible, kinetic gas models would need to consider an additional gas exchange route that might be functional at great depths within the odontocetes. Other adaptations potentially mitigating and defending against deleterious nitrogen gas emboli have been proposed (Blix et al., 2013). Researchers have also considered the accumulation of carbon dioxide produced during periods of high activity by an animal, theorizing that accumulating carbon dioxide, which cannot be removed by gas exchange below the depth of lung collapse, might also facilitate the formation of bubbles in nitrogen-saturated tissues (Bernaldo de Quiros et al., 2012; Fahlman et al., 2014). In all these cases, the hypotheses have received little in the way of experimentation to evaluate whether they are supported, thus leaving many unknowns as to the predictive accuracy of modeling efforts.

The appearance of extensive bubble and fat emboli in beaked whales was unique to a small number of strandings associated with certain high-intensity sonar events; the phenomenon has not been observed to the same degree in other stranded marine mammals, including other beaked whale strandings not associated with sonar use. It is uncertain as to whether there is some more easily triggered mechanism for this phenomenon specific to beaked whales or whether the phenomenon occurs only following rapidly occurring stranding events (i.e., when whales are not capable of sufficiently decompressing). Nevertheless, based on the rarity of observations of bubble pathology, the potential for nitrogen decompression sickness due to exposure to the Action Proponents' sound sources is considered discountable.

D.4.7.1.3 Strandings Associated with Sonar

A stranding occurs when a marine mammal is found dead, either ashore or in the water, or is found alive, but is unable to return to the water, needs medical attention, or is unable to return to its natural habitat without assistance. Marine mammals face many threats in their environment, and many of these factors, both natural and anthropogenic, may cause or contribute to a stranding. These include disease, vessel strike, entanglement, marine debris, algal blooms, pollution, starvation, weather events, and oceanographic changes (National Marine Fisheries Service, 2019a). Decomposition, buoyancy, scavenging by other marine species, wave damage, and other oceanic conditions complicate the assessment of marine mammal carcasses (Moore et al., 2020). In most instances, even for the more thoroughly investigated strandings involving post-stranding data collection and necropsies, the cause (or causes) for strandings remains undetermined.

Strandings of deep diving odontocetes, specifically beaked whales, have been correlated with naval anti-submarine warfare sonar use. D'Amico et al. (2009) reviewed global beaked whale mass strandings (two or more marine mammals of the same species other than a mother/calf pair) occurring between 1950 and 2004. The review suggested that 12 of 126 of the strandings could be considered to have coincided in space and time with naval activity that may have included mid-frequency active sonar use. Sonar use during exercises involving the U.S. Navy has been identified as a contributing cause or factor in five specific mass stranding events: Greece in 1996; the Bahamas in March 2000; Madeira Island, Portugal in 2000; the Canary Islands in 2002, and Spain in 2006 (Cox et al., 2006; Fernandez, 2006), as described in the Navy's technical report titled *Marine Mammal Strandings Associated with U.S. Navy Sonar Activities* (U.S. Department of the Navy, 2017a). These five mass strandings have resulted in about 40 known cetacean deaths consisting mostly of beaked whales and with close linkages to mid-frequency active sonar activity. Two minke whales also stranded in shallow water after the U.S. Navy training event in the Bahamas in 2000, although these animals were successfully returned to deep water with no physical examinations; therefore, no final conclusions were drawn on whether the sonar led to their stranding (Filadelfo et al., 2009a; Filadelfo et al., 2009b; U.S. Department of Commerce & U.S. Department of the Navy, 2001). Factors that were associated with these strandings included steep bathymetry, multiple hull-mounted platforms using sonar simultaneously, constricted channels, and acoustic propagation conditions that trapped sound near the sea surface (i.e., strong surface ducts). While no other beaked whale strandings have since been correlated to U.S. Navy sonar use, Simonis et al. (2020) claimed a correlation between sonar and beaked whale strandings in the Mariana Islands between 2007 and 2019. This analysis, however, relied on incomplete or inaccurate assumptions about actual U.S. Navy sonar use around the Mariana Islands, such as news reports about Navy activities rather than actual records of sonar use. In a subsequent analysis, the Center for Naval Analysis found no statistically significant correlation of beaked whale strandings around the Mariana Islands with actual use of U.S. Navy sonar based on the complete classified record of all U.S. Navy sonar used (Center for Naval Analysis, 2020).

Sonar was considered a plausible cause in other stranding investigations for other species: coastal bottlenose dolphins in California (Danil et al., 2021) and melon-headed whales in Hawaii (Southall et al., 2006). It should be noted that other factors were considered plausible causes in these investigations, such as a fisheries interaction for the bottlenose dolphins in California or lunar cycles for the melon-headed whales in Hawaii. In Alaska, Savage et al. (2021) suggested that historical Stejneger's beaked whale strandings could have co-occurred with Navy sonobuoy use but present no evidence of correlation.

Multiple hypotheses regarding the relationship between non-impulsive sound exposure and stranding have been proposed (see Bernaldo de Quirós et al., 2019). These range from direct impact of the sound on the physiology of the marine mammal, to behavioral reactions contributing to altered physiology (e.g., "gas and fat embolic syndrome") (Fernandez et al., 2005; Jepson et al., 2003; Jepson et al., 2005), to behaviors directly contributing to the stranding (e.g., beaching of fleeing animals). Unfortunately, without direct observation of not only the event but also the underlying process, and given the potential for artefactual evidence (e.g., chronic condition, previous injury) to complicate conclusions from the post-mortem analyses of stranded animals (Cox et al., 2006), it has not been possible to determine with certainty the exact mechanism underlying these strandings. Based on examination of the above sonar-associated strandings, Bernaldo de Quirós et al. (2019) list diagnostic features, the presence of all of which suggest gas and fat embolic syndrome for beaked whales stranded in association with sonar exposure. Bernaldo de Quirós et al. (2019) observed that, to date, strandings which have a confirmed association with naval exercise have exhibited all seven of the following diagnostic features:

1. Individual or multiple animals stranded within hours or a few days of an exercise in good body condition
2. Food remnants in the first gastric compartment ranging from undigested food to squid beaks
3. Abundant gas bubbles widely distributed in veins (subcutaneous, mesenteric, portal, coronary, subarachnoid veins, etc.) composed primarily of nitrogen in fresh carcasses
4. Gross subarachnoid and/or acoustic fat hemorrhages
5. Microscopic multi-organ gas and fat emboli associated with bronchopulmonary shock
6. Diffuse, mild to moderate, acute, monophasic myonecrosis (hyaline degeneration) with "disintegration" of the interstitial connective tissue and related structures, including fat deposits, and their replacement by amorphous hyaline material (degraded material) in fresh and well-preserved carcasses
7. Multi-organ microscopic hemorrhages of varying severity in lipid-rich tissues such as the central nervous system, spinal cord, and the coronary and kidney fat when present

Historically, stranding reporting and response efforts have been inconsistent, although they have improved considerably over the time. Although reporting forms have been standardized nationally, data collection methods, assessment methods, detail of reporting, and procedures vary by region and are not yet standardized across the United States. Conditions such as weather, time, location, and decomposition state may also affect the ability to thoroughly examine a specimen (Carretta et al., 2016b; Moore et al., 2013). Because of this, the current ability to interpret long-term trends in marine mammal stranding is limited. While the investigation of stranded animals provides insight into the types of threats marine mammal populations face, investigations are only conducted on a small fraction of the total number of strandings that occur, limiting the understanding of the causes of strandings (Carretta et al., 2016a).

D.4.7.2 Direct Injury due to Explosives

Explosive injury to marine mammals would consist of primary blast injury, which refers to those injuries that result from the compression of a body exposed to a blast wave and is usually observed as barotrauma of gas-containing structures (e.g., lung and gut) and structural damage to the auditory system (Greaves et al., 1943; Office of the Surgeon General, 1991; Richmond et al., 1973). The near instantaneous high magnitude pressure change near an explosion can injure an animal where tissue material properties significantly differ from the surrounding environment, such as around air-filled cavities in the lungs or gastrointestinal tract. Large pressure changes at tissue-air interfaces in the lungs and gastrointestinal tract may cause tissue rupture, resulting in a range of injuries depending on degree of exposure. The lungs are typically the first site to show any damage, while the solid organs (e.g., liver, spleen, and kidney) are more resistant to blast injury (Clark & Ward, 1943). Odontocetes can also incur hemorrhaging in the acoustic fats in the melon and jaw (Siebert et al., 2022). Recoverable injuries would include slight lung injury, such as capillary interstitial bleeding, and contusions to the gastrointestinal tract. More severe injuries, such as tissue lacerations, major hemorrhage, organ rupture, or air in the chest cavity (pneumothorax), would significantly reduce fitness and likely cause death in the wild. Rupture of the lung may also introduce air into the vascular system, producing air emboli that can cause a stroke or heart attack by restricting oxygen delivery to critical organs.

If an animal is exposed to an explosive blast underwater, the likelihood of injury depends on the charge size, the geometry of the exposure (distance to the charge, depth of the animal and the charge), and the size of the animal. In general, models predict that an animal would be less susceptible to injury near the water surface because the pressure wave reflected from the water surface would interfere with the direct path pressure wave, reducing positive pressure exposure (Goertner, 1982; Yelverton & Richmond, 1981). This is shown in the records of humans exposed to blast while in the water, which show that the gastrointestinal tract was more likely to be injured than the lungs, likely due to the shallower exposure geometry of the lungs (i.e., closer to the water surface) (Lance et al., 2015). Susceptibility would increase with depth, until normal lung collapse (due to increasing hydrostatic pressure) and increasing ambient pressures again reduce susceptibility (Goertner, 1982).

The only known occurrence of mortality or injury to a marine mammal due to a Navy training event involving explosives occurred in March 2011 in nearshore waters off San Diego, California, at the Silver Strand Training Complex. This area had been used for underwater demolitions training for at least three decades without prior known incident. On this occasion, however, a group of approximately 100 to 150 long-beaked common dolphins entered the mitigation zone surrounding an area where a time-delayed firing device had been initiated on an explosive with a NEW of 8.76 pounds (lb.) (3.97 kg) placed at a depth of 48 ft. (14.6 m). Approximately one minute after detonation, three animals were observed dead at the surface. The Navy recovered those animals and transferred them to the local stranding network for necropsy. A fourth animal was discovered stranded and dead 42 NM to the north of the detonation three days later. It is unknown exactly how close those four animals were to the detonation. Upon necropsy, all four animals were found to have sustained typical mammalian primary blast injuries (Danil & St Leger, 2011).

Relatively little is known about auditory system trauma in marine mammals resulting from explosive exposure, although it is assumed that auditory structures would be vulnerable to blast injuries. Auditory trauma was found in two humpback whales that died following the detonation of a 5,000 kg explosive used off Newfoundland during demolition of an offshore oil rig platform (Ketten et al., 1993), but the proximity of the whales to the detonation was unknown. Eardrum rupture was examined in submerged terrestrial mammals exposed to underwater explosions (Richmond et al., 1973; Yelverton et al., 1973); however, results may not be applicable to the anatomical adaptations for underwater hearing in marine mammals. In this discussion, primary blast injury to auditory tissues is considered gross structural tissue damage distinct from threshold shift or other auditory effects.

Controlled tests with a variety of lab animals (mice, rats, dogs, pigs, sheep, and other species) are the best data sources on actual injury to mammals due to underwater exposure to explosions. In the early

1970s, the Lovelace Foundation for Medical Education and Research conducted a series of tests in an artificial pond at Kirtland Air Force Base, New Mexico, to determine the effects of underwater explosions on mammals, with the goal of determining safe ranges for human divers. The resulting data were summarized in two reports (Richmond et al., 1973; Yelverton et al., 1973). Specific physiological observations for each test animal are documented in Richmond et al. (1973). Gas-containing internal organs, such as lungs and intestines, were the principle damage sites in submerged terrestrial mammals; this is consistent with earlier studies of mammal exposures to underwater explosions in which lungs were consistently the first areas to show damage, with less consistent damage observed in the gastrointestinal tract (Clark & Ward, 1943; Greaves et al., 1943).

In the Lovelace studies, the first positive acoustic impulse was found to be the metric most related to degree of injury, and size of an animal's gas-containing cavities was thought to play a role in blast injury susceptibility. For these shallow exposures of small terrestrial mammals (masses ranging from 3.4 to 50 kg) to underwater detonations, Richmond et al. (1973) reported that no blast injuries were observed when exposures were less than 6 pounds per square inch per millisecond (psi-ms) (40 pascal seconds [Pa-s]), no instances of slight lung hemorrhage occurred below 20 psi-ms (140 Pa-s), and instances of no lung damage were observed in some exposures at higher levels up to 40 psi-ms (280 Pa-s). An impulse of 34 psi-ms (230 Pa-s) resulted in about 50 percent incidence of slight lung hemorrhage. About half of the animals had gastrointestinal tract contusions (with slight ulceration, i.e., some perforation of the mucosal layer) at exposures of 25–27 psi-ms (170-190 Pa-s). Lung injuries were found to be slightly more prevalent than gastrointestinal tract injuries for the same exposure. The anatomical differences between the terrestrial animals used in the Lovelace tests and marine mammals are summarized in Fetherston et al. (2019). Goertner (1982) examined how lung cavity size would affect susceptibility to blast injury by considering both marine mammal size and depth in a bubble oscillation model of the lung; however, the Goertner (1982) model did not consider how tissues surrounding the respiratory air spaces would reflect shock wave energy or constrain oscillation (Fetherston et al., 2019).

Goertner (1982) suggested a peak overpressure gastrointestinal tract injury criterion because the size of gas bubbles in the gastrointestinal tract are variable, and their oscillation period could be short relative to primary blast wave exposure duration. The potential for gastrointestinal tract injury, therefore, may not be adequately modeled by the single oscillation bubble methodology used to estimate lung injury due to impulse. Like impulse, however, high instantaneous pressures may damage many parts of the body, but damage to the gastrointestinal tract is used as an indicator of any peak pressure-induced injury due to its vulnerability.

Because gas-containing organs are more vulnerable to primary blast injury, adaptations for diving that allow for collapse of lung tissues with depth may make animals less vulnerable to lung injury with depth. Adaptations for diving include a flexible thoracic cavity, distensible veins that can fill space as air compresses, elastic lung tissue, and resilient tracheas with interlocking cartilaginous rings that provide strength and flexibility (Ridgway, 1972). Denk et al. (2020) found intra-species differences in the compliance of tracheobronchial structures of post-mortem cetaceans and pinnipeds under diving hydrostatic pressures, which would affect depth of alveolar collapse. Older literature suggested complete lung collapse depths at approximately 70 m for dolphins (Ridgway & Howard, 1979) and 20 to 50 m for phocid seals (Falke et al., 1985; Kooyman et al., 1972). Follow-on work by Kooyman and Sinnett (1982), in which pulmonary shunting was studied in harbor seals and sea lions, suggested that complete lung collapse for these species would be about 170 m and about 180 m, respectively. Evidence in sea lions suggests that complete collapse might not occur until depths as great as 225 m; although the depth of collapse and depth of the dive are related, sea lions can affect the depth of lung collapse by varying the amount of air inhaled on a dive (McDonald & Ponganis, 2012). This is an important consideration for all divers who can modulate lung volume and gas exchange prior to diving via the degree of inhalation and during diving via exhalation (Fahlman et al., 2009); indeed, there are noted differences in pre-dive respiratory behavior, with some marine mammals exhibiting pre-dive exhalation to reduce the lung volume (e.g., phocid seals Kooyman et al., 1973).

D.4.8 Population Consequences to Marine Mammals from Acoustic Stressors

This section summarizes the best available science on consequences to marine mammal populations from exposure to acoustic sources.

D.4.8.1 Long-Term Consequences to Populations

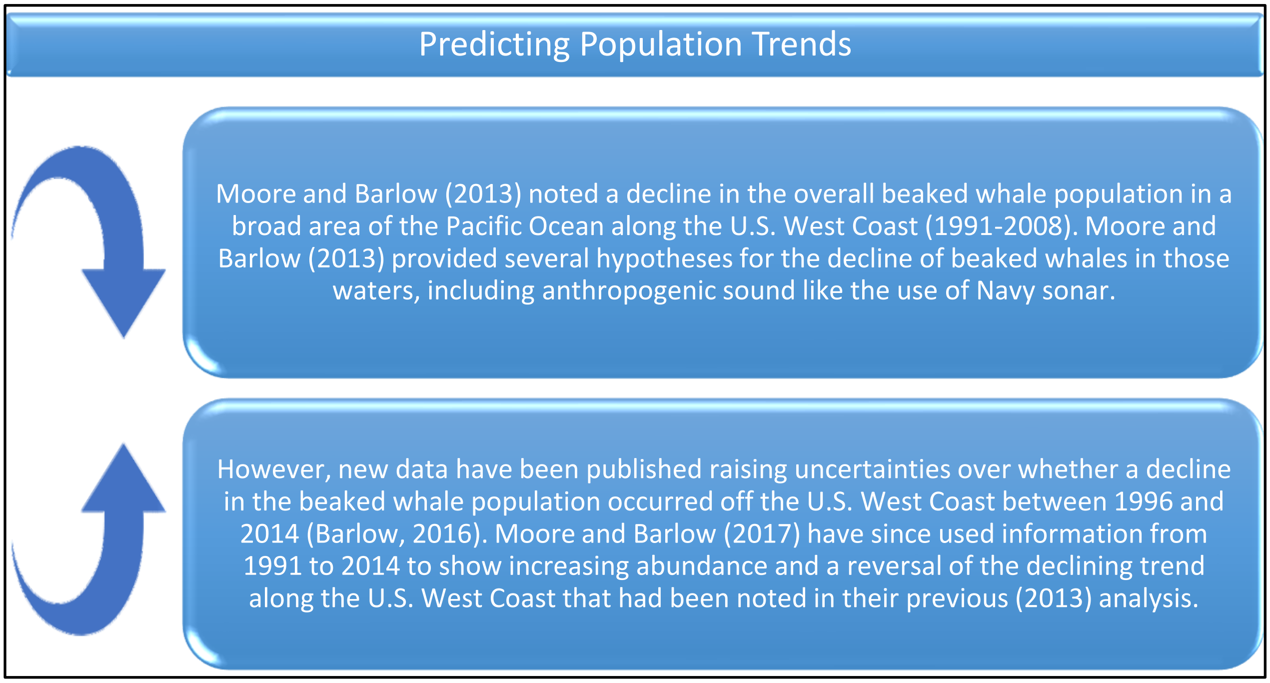
The long-term consequences of disturbance (anthropogenic or environmental), hearing loss, chronic masking, and short-term or chronic physiological stress are difficult to predict because of the different factors experienced by individual animals, such as context of stressor exposure, underlying health conditions, and other environmental or anthropogenic stressors. Linking these non-lethal effects on individuals to changes in population growth rates requires long-term data, which is lacking for many populations.

An important variable to consider is duration of disturbance. Severity scales used to assess behavioral responses to acute sound exposures are not appropriate to apply to sustained or repeated (chronic) exposures, as the focus has shifted from the immediate impacts to an individual to the health of a population over time (Southall et al., 2021). For example, short-term costs experienced over the course of a week by an otherwise healthy individual may be recouped over time after exposure to the stressor ends. These short-term costs would be unlikely to result in long-term consequences to that individual or to that individual's population. Comparatively, long-term costs accumulated by otherwise healthy individuals over an entire season, year, or throughout a life stage would be less easily recouped and more likely to result in long-term consequences to that individual or population.

Marine mammals exposed to frequent or intense human activities may leave the area, habituate to the activity, or tolerate the disturbance and remain in the area (Wartzok et al., 2003). Highly resident or localized populations may also stay in an area of disturbance because the cost of displacement may be higher than the cost of remaining (Forney et al., 2017). An apparent lack of response (e.g., no displacement or avoidance of a sound source) may not necessarily mean there is no cost to the individual or population, as some resources or habitats may be of such high value that animals may choose to stay, even when experiencing the consequences of stress, masking, or hearing loss (Forney et al., 2017).

Longer term displacement can lead to changes in abundance or distribution patterns of the species in the affected region (Bejder et al., 2006b; Blackwell et al., 2004; Teilmann et al., 2006). For example, gray whales in Baja California abandoned a historical breeding lagoon in the mid-1960s due to an increase in dredging and commercial shipping operations, and only repopulated the lagoon after shipping activities had ceased for several years (Bryant et al., 1984). Mysticetes in the northeast tended to adjust to vessel traffic over a number a of years, trending towards more neutral behavioral responses to passing vessels (Watkins, 1986), indicating that some animals may habituate to high levels of human activity. A study on bottlenose dolphin responses to vessel approaches found that lesser reactions in populations of dolphins regularly subjected to high levels of vessel traffic could be a sign of habituation, or it could be that the more sensitive animals in this population previously abandoned the area of higher human activity (Bejder et al., 2006a).

Population characteristics such as if a population is open or closed to immigration and emigration can influence sensitivity to disturbance as well; closed populations could not withstand a higher probability of disturbance compared to open populations with no limitation on food (New et al., 2020). Still, predicting population trends or long-term displacement patterns due to anthropogenic disturbance is challenging due to limited information and survey data for many species over sufficient temporal and spatial scales, as well as a full understanding of how other factors, such as oceanographic oscillations and climate change, affect presence (e.g., see Figure D.4-4).



Sources: (Barlow, 2016; Moore & Barlow, 2017; Moore & Barlow, 2013)

Note: Real-world displacement trends are complicated. This example demonstrates how the abundance, and the implied trend of habitat displacement, of beaked whales in an area changed depending on the years analyzed.

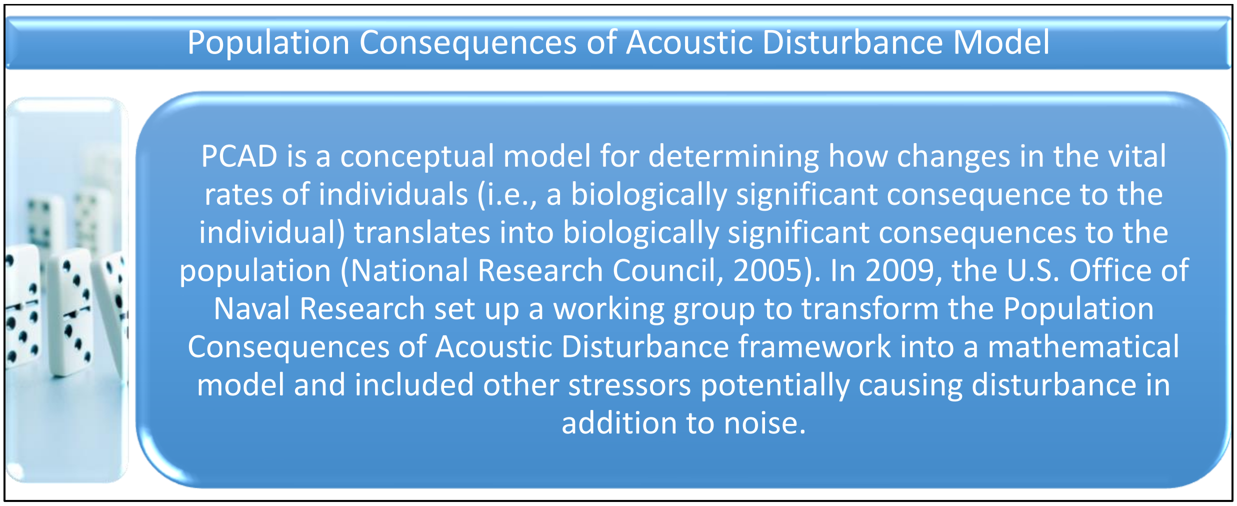
Figure D.4-4: Predicting Population Trends

D.4.8.2 Population Consequences of Disturbance Models

Scientists link short-term effects to individuals from disturbance (anthropogenic impacts or environmental change) to long-term population consequences using population models. Population models accept inputs for the population size and changes in vital rates of the population, such as the mean values for survival age, lifetime reproductive success, and recruitment of new individuals into the population (i.e., raising self-sufficient pups and calves past the weaning stage), to predict changes in population dynamics (e.g., population growth rate). These efforts often rely on bioenergetic models, or energy budget models, which analyze energy intake from food and energy costs for life functions, such as maintenance, growth, and reproduction, either at the individual or population level (Pirotta, 2022). There is high uncertainty around many parameters in these models {e.g., Hütt, 2023, `#21208}. Model sensitivity analyses have identified the most consequential parameters, including prey characteristics, feeding processes, energy expenditure, body size, energy storage, and lactation capability (Pirotta, 2022).

The National Research Council committee on Characterizing Biologically Significant Marine Mammal Behavior developed an initial conceptual model to link acoustic disturbance to population effects and inform data and research needs (National Research Council, 2005) (Figure D.4-5). This Population Consequences of Acoustic Disturbance, or PCAD, conceptual model linked parameters as illustrated in Figure D.4-6.

In its report, the committee found that the relationships between biologically significant consequences and population effects were relatively well understood, but that the relationships between the other components of the model were not well-known or easily observed.



Source: (National Research Council, 2005)

Figure D.4-5: Population Consequences of Acoustic Disturbance (PCAD) Model Definition

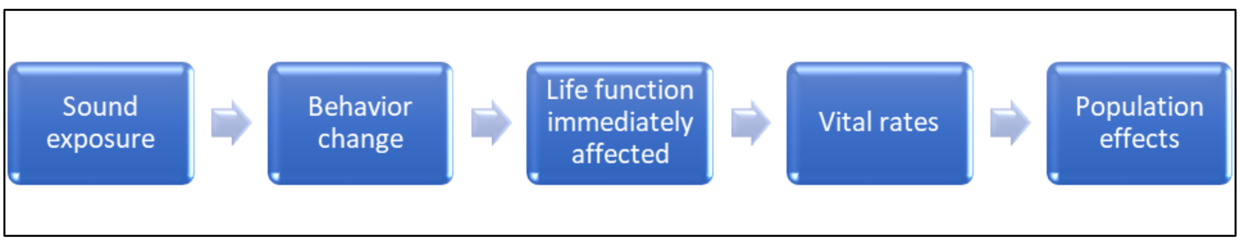
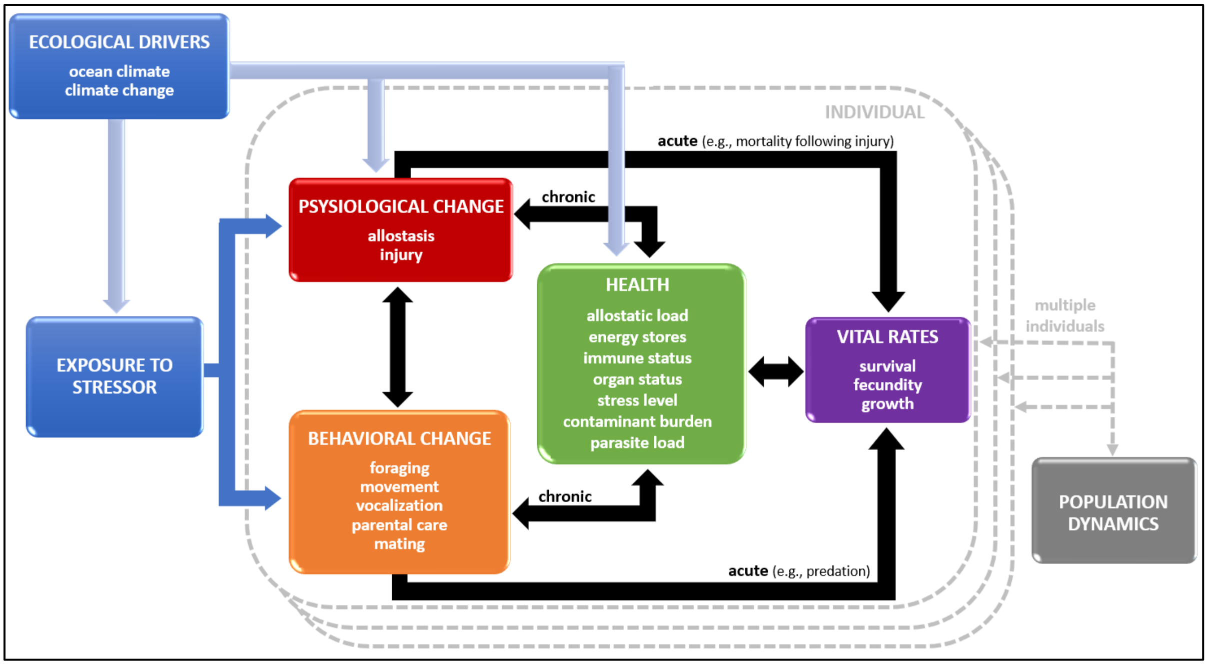


Figure D.4-6: PCAD Model Parameters Flowchart

Building on the PCAD framework, the PcoD conceptual model was developed by an Office of Naval Research working group. The PCOD model considers all types of disturbance, not solely anthropogenic or acoustic, and incorporates physiological changes, such as stress or injury, along with behavioral changes as a direct result of disturbance (National Academies of Sciences Engineering and Medicine, 2017). It also links these changes to both acute effects on vital rates (e.g., survival, fecundity) and chronic effects on health (e.g., energy stores, stress, immunity) (New et al., 2014; Pirotta et al., 2018a). Examples of acute effects include immediate injury, such as vessel strike; immediate health impacts, such as toxic algae exposure; or behavioral responses that increase predation risk (National Academies of Sciences Engineering and Medicine, 2017). Examples of chronic effects include exposure to persistent contaminants and permanent hearing loss (National Academies of Sciences Engineering and Medicine, 2017). These relationships are shown in Figure D.4-7.



Sources: Adapted from Pirotta et al. (2018a), National Academies of Sciences Engineering and Medicine (2017), New et al. (2014), and Keen et al. (2021)

Figure D.4-7: The Population Consequences of Disturbance Conceptual Model

The Population Consequences of Disturbance (PcoD) model identifies the types of data that would be needed to assess population-level impacts. These data are lacking for many marine mammal species (Booth et al., 2020). Southall et al. (2021) states that future modeling and population simulation studies can help determine population-wide long-term consequences and impact analysis. However, the method to do so is still developing, as there are gaps in the literature, possible sampling biases, and results are rarely ground-truthed, with a few exceptions (Booth et al., 2022; Schwarz et al., 2022). Nowacek et al. (2016) reviewed technologies such as passive acoustic monitoring, tagging, and the use of unmanned aerial vehicles which can improve scientists' abilities to study these model inputs and link behavioral changes to individual life functions and ultimately population-level effects. Relevant data needed for improving analyses of population-level consequences resulting from disturbances will continue to be collected during projects funded by the Navy's marine species monitoring program.

Multiple case studies across marine mammal taxonomic groups have been conducted following the PcoD framework (see Table D.4-11). From these studies, Keen et al. (2021) identified themes and contextual factors relevant to assessing impacts to populations due to disturbance (see Figure D.4-8).

life-history traits	movement ecology	– resident: individuals occupy small home ranges compared to population's range, year-round and prolonged exposure potential – nomadic: individuals move over population's range without spatial or temporal consistency, year-round and unpredictable exposure potential – migratory: individuals undertake annual or seasonal movements between sites within population's range, seasonal exposure potential – demographic: age, sex, and reproductive status influence spatial and temporal movements
	reproductive strategy	– income breeder: feeds during lactation, vulnerable to prolonged foraging loss during lactation – capital breeder: stores energy prior to parturition for lactation, vulnerable to prolonged foraging loss during gestation
	body size	– body size: a larger body size may buffer against periods of reduced prey availability – life stage: juveniles and young mothers may be more sensitive to reduced food availability due to physiological constraints related to body size
	pace of life	– fast pace of life: reproduction is more sensitive to reduced or lost foraging, but populations will be quicker to recover due to high reproductive rates and short generation times – slow pace of life: reproduction is more resilient to reduced or lost foraging, but populations will be slower to recover, particularly if adult survival is impacted, due to low reproductive rates and long generation times
disturbance source characteristics	overlap with biologically important habitats	– the effect of disturbance is strongly influenced by whether it overlaps with biologically important habitats when individuals are present – avoiding biologically important habitats will provide opportunities for individuals to compensate for reduced or lost foraging if large portions of their range are disturbed
	duration and frequency	– continuous disruption will have a greater impact than intermittent disruption – reducing the duration and frequency of disturbance or incorporating breaks between disturbance events may allow individuals to recover – energy loss can be translated into days of disturbance to inform area- or population-specific disturbance caps
	nature and context	– the probability and severity of individual responses depends on the interactions between the type and nature of the disturbance source and the context of the exposure – incorporating context into risk assessments can significantly reduce the uncertainty in managing populations and mitigating effects
environmental conditions	natural variability in prey availability	– sensitivity to disturbance strongly depends on the availability of prey in the environment – avoiding periods of low productivity and increased energy intake can reduce the potential for interactive and cumulative effects
	climate change	– climate vulnerability assessments can help identify populations most vulnerable to climate change and the factors contributing to their vulnerability – climate change coupled with disturbance may have interactive and cumulative effects that affect reproductive success and survival

Source: Table from Keen et al. (2021)

Figure D.4-8: Emerging Themes in PcoD Models that Should Be Considered When Assessing the Likelihood and Duration of Exposure and the Sensitivity of a Population to Disturbance Identified by Keen et al. (2021)

Table D.4-11: Published Models using the Population Consequences of Disturbance Framework

Species	*Disturbance/ PcoD Variables*[1]	*Findings*
Minke whale	Whale watching activities/ M, R, D	Whale watching interactions decreased (42%) feeding and increased (7%) non-feeding activity, but cumulative bioenergetic cost remained low (88,018 kJ) even for the most exposed whale which resulted in a minor decrease in body condition safely below the threshold which would impact fetal growth. Impacts would be larger if vessels interacted with whales significantly more during the feeding season (Christiansen & Lusseau, 2015).
Blue whale	Simulated seismic survey/ M, B, D, N	Migrating blue whales are more likely to go long periods without exposure but are more likely to be exposed to seismic during seasonal presence, like in the California Current feeding grounds. Time and proportion of whales exposed increased (< 19%) as stressor increased (Costa et al., 2016a).
	Five scenarios of natural (El Nino or unprecedented change) and unspecified anthropogenic disturbances modeled as lost foraging time (i.e., 0%, habitat displacement, or 50%)/ M, R, B, D, N, V	Short environmental changes like El Nino reduced calf recruitment a little, but unprecedented climate changes impacted fecundity much more (i.e., increased abortions). Weak anthropogenic disturbances over a diffuse area (e.g., ship traffic, whale watching) had little effect on fecundity. Impact from intense, continuous noise (e.g., seismic, pile driving) depended on females' response. If they stayed in the area, body condition decreased and rate of abortions and starvation increased; if they moved to feed elsewhere there was no long-term effect (Pirotta et al., 2018b).
	Natural and unspecified anthropogenic disturbances modeled as lost foraging time/ M, R, S, P, B, D, N, V, C	Blue whale model above was expanded to encompass females' entire lives. Increased frequency of climate change decreased fecundity gradually (e.g., calves weaned early). High levels of anthropogenic disturbance only impacted vital rates if disturbance occurred for 1 year in all locations of the home range, or if disturbance was localized in summer feeding grounds. Repeated disturbance decreased reproductive success and survival of young whales (Pirotta et al., 2019).
	Sonar/ M, N, V	Activity budgets, lunging rates and ranging pattern caused variability in the predicted cost of sonar disturbance. With disturbance, whale reproductive strategies resulted in lower fitness (Pirotta et al., 2021).
Gray whale	Unspecified "anthropogenic disturbance"/ M, R, P, D	Western gray whales had greater energetic requirements during the longer migration to Baja California and China, compared to the shorter migration of Eastern gray whales, so were more sensitive to energy lost through disturbance (Villegas-Amtmann et al., 2017).
	Seismic surveys/ M, R, S, P, B, N, V	Direct disturbance or displacement from nearshore (less energy-rich) areas had little impact on population abundance, but females deprived access to energy-rich offshore summer feeding grounds decreased reproductive success and adult survival, leading to long-term consequences on population abundance (McHuron et al., 2021).
Long-finned pilot whale	Unspecified disturbance modeled as "lost foraging days" for mother-calf pairs (e.g., habitat displacement)/ R, S, P, D, V	Short disturbances increased mortality of calves born to young mothers, and longer disturbances increased calf mortality (born to older mothers) and decreased the life expectancy for mothers, including starvation during lactation periods. Disturbance impacted whales faster in winter (5+ days) than in summer (20+ days) (Hin et al., 2019).

Species	*Disturbance/ PcoD Variables[1]*	*Findings*
	Unspecified "anthropogenic disturbance"/ R, S, P, D, V	Modeled disturbance decreased reproductive strategies and fitness. When resources were not evenly distributed, cautious strategies and knowledge of resource variation was advantageous (Pirotta et al., 2020).
	Unspecified disturbance modeled as "lost foraging days" (e.g., habitat displacement)/ R, S, P, D, V	Disturbance decreased population density (e.g., young lactating females) and increased prey availability, which resulted in improved body condition in the population overall and no net impact on lifetime reproductive output, suggesting that fitness markers may not indicate population effects (Hin et al., 2021).
Humpback whale	Simulated seismic survey/ M, B, D, N	Whale populations that foraged for krill over wide areas (West Antarctic Peninsula) were exposed to seismic less, resulting in less disturbed foraging behavior. In contrast, Bering Sea humpback whales hunted fish over a much smaller/ localized area, and have a limited range for foraging where more whales (90%) were exposed to seismic and interrupted while foraging (Costa et al., 2016a).
	Seismic surveys/ M, R, S, P, N	PcoD models can be used for predicting population consequences or making management decisions, depending if forwards or backward approach is used (Dunlop et al., 2021).
North Atlantic Right Whale	Fishing gear entanglements/ D, N, V, C	Entanglement and limited prey availability can be considered continuous stressors (e.g., prey density changes throughout range and entanglement level), and compounded impacts as entanglement decreases foraging success. When there isn't enough empirical information, a mechanistic model can be used to simulate the interaction between varying levels of entanglement, feeding rate and maximum prey intake (Pirotta et al., 2022b).
Beaked whale	Unspecified "non-lethal" disturbance/ R, S, P, B, V	Different assumptions for duration of gestation and lactation can alter model results for mother and calf mortality. Six beaked whale species were very sensitive, Baird's had a quick time to weaning, and Longman's needed higher quality habitat. Consistent long-term disturbance with minor reduction in energy intake may have same effect as strong, short-term disturbance that halts energy intake. Many conservative assumptions were used for this model since many parameters were unknown for 21 beaked whale species (New et al., 2013b).
	Sonar/ M, B, D, N	Beaked whales at SOAR and AUTEC ranges exposed to MFA navy sonar could have outcomes ranging from slight increase in population abundance to population extinction, depending on the interaction of sonar use, habitat quality, and the whales' behavioral response to sonar (i.e., displacement, cessation of feeding, both, or no response) (Hin et al., 2023)
Killer whale	Vessel strike, vessel noise, polychlorinated biphenyls contamination/ R, P, B, V	Both Northern and Southern killer whale populations were impacted by the interaction of low prey abundance with vessel strike, vessel noise, and contaminants, but more research is needed to validate the mechanisms of all non-prey variables (Murray et al., 2021).
Harbor porpoise	Wind turbine noise, ship noise/ M, R, S, P, N	Even assuming a 10% reduction in population size, if prey is impacted up to two days, the presence of ships and wind turbines did not deplete the population (Nabe-Nielsen et al., 2014).
	Pile driving/ M, R, S, P, D, V	Predicted a < 0.5% decline in harbor porpoise population size from wind farm construction in worst case scenario (King et al., 2015).

Species	*Disturbance/ PcoD Variables*[1]	*Findings*
	Seismic surveys/ M, R, S, P, N, V	Seismic activity in May had less impact on porpoise health and reproduction, and seismic in September had more impact (Gallagher et al., 2021).
Sperm whale	Oil spill, seismic survey/ M, R, S, P, B, D, N	10-year model projected population reductions from the oil spill and further declines when compounded with exposure to seismic surveys. Amount of additional population decline due to seismic noise depended on modeling method (i.e., single step-functions had more impacts than functions with multiple steps and frequency weighting). Resilient populations (e.g., able to make up reserves through increased foraging) mediate impacts from both disturbances (Farmer et al., 2018a).
	Unspecified "anthropogenic disturbance" associated with reduced foraging efficiency/ R, S, P, D	Mothers with calves were most vulnerable to foraging disruptions due to high energetic cost of lactation (Farmer et al., 2018b).
Bottlenose dolphin	Climate change, ship noise, fisheries bycatch, epizootic (morbillivirus)/ R, S, P, D, B, V, C	5-year model predicted that epizootic and climate change scenarios would have the largest impact on population size and fecundity. Fisheries interactions and shipping noise disturbance had little overall impact on population abundances in either location, even in the most extreme impact scenarios modeled (Reed et al., 2020).
Northern elephant seal	Unspecified "environmental change" or "anthropogenic disturbance"/ M, R, P, D	Predicted that populations of elephant seals are relatively robust even with > 50% reduction in foraging trips (only a 0.4% population decline in the following year) (New et al., 2014).
	Continuous acoustic disturbance/ M, R, N	Elephant seals would be less impacted than California sea lions since their foraging range and transit area is more expansive. Negligible impacts on reproduction and pup survival rates (Costa et al., 2016b).
Harbor seal	Pile driving/ M, R, S, P, D	Worst-case scenario PCAD model predicted that the 18% of harbor seals with PTS from wind farm construction noise exposure could translate to higher mortality rates or lower reproductive rates for the population (Thompson et al., 2013b).
California sea lion	Continuous acoustic disturbance/ M, R, N	California sea lions were disturbed for a longer period than elephant seals because the sea lions' range (foraging and transit area) is more limited. However, even animals exposed for the longest periods had negligible modeled impacts on their reproduction and pup survival rates (Costa et al., 2016b).
	Generalized disturbance/ M, R, S, P, D	Very short duration disturbances/responses led to little change, particularly if the disturbance was a single event, and changes in the timing of the event in the year had little effect. Relatively short disturbances or mild responses, when a disturbance was modeled as recurring, resulted in a fewer number of adults and pups. The effects weren't noticeable for several years, as the impacts on pup survival did not affect the population until those pups were mature (McHuron et al., 2018a).
11 mysticete and odontocete species[2]	Sonar/ M, S, P, V	Short-term energetic cost was influenced more by lost foraging opportunities than increased locomotor effort during avoidance. Mysticetes incurred more energetic costs that odontocetes, even during mild behavioral responses to mid-frequency active sonar (Czapanskiy et al., 2021).

[1]If an anthropogenic disturbance was modeled it is included, along with the variables included in the PcoD model, such as life-history traits (M= movement ecology, R= reproductive strategy, S= body size, P= pace of life), disturbance of source

Species	Disturbance/ PcoD Variables[1]	Findings

characteristics (B= overlap with biologically important habitats, D= duration and frequency, N= nature and context), and environmental conditions (V= natural variability in prey, C= climate change). Notation adapted from Keen et al. (2021).
[2]11 species studied: harbor porpoise, Risso's dolphin, Bainville's beaked whale, short-finned pilot whale, long-finned pilot whale, goose-beaked whale, minke whale, sperm whale, humpback whale, fin whale, and blue whale (Czapanskiy et al., 2021).
Notes: % = percent; > = greater than; kJ = kilojoule; PCAD = Population Consequences of Acoustic Disturbance; PcoD = Population Consequences of Disturbance; PTS = permanent threshold shift

D.4.8.3 Movement Ecology

A population's movement ecology determines the potential for temporal and spatial overlap with a disturbance. Resident populations or populations that rely on spatially limited habitats for critical life functions, such as foraging or breeding, would be at greater risk of repeated or chronic exposure to disturbances than populations that are wide-ranging relative to the footprint of a disturbance (Keen et al., 2021). Even for the same species, differences in habitat use between populations can result in different potential for repeated exposure to individuals for a similar stressor (Costa et al., 2016a). The location and radius of disturbance can impact how many animals are exposed and for how long (Costa et al., 2016b). While some models have shown the advantages of populations with larger ranges, namely the decreased chance of being exposed (Costa et al., 2016b), it's important to consider that for some species, the energetic cost of a longer migration could make a population more sensitive to energy lost through disturbance (Villegas-Amtmann et al., 2017). In addition to ranging patterns, a species' activity budgets and lunging rates can cause variability in their predicted cost of disturbance as well (Pirotta et al., 2021).

D.4.8.4 Resource Dependence

Bioenergetics frameworks that examine the impact of foraging disruption on body reserves of individual whales found that rates of daily foraging disruption can predict the number of days to terminal starvation for various life stages (Farmer et al., 2018b). Similarly, when a population is displaced by a stressor, and only has access to areas of poor habitat quality (i.e., low prey abundance) for relocation, bioenergetic models may be more likely to predict starvation, longer recovery times, or extinction (Hin et al., 2023). There is some debate over the use of blubber thickness as a metric of cetacean energy stores and health, as marine mammals may not use their fat stores in a similar manner to terrestrial mammals (Derous et al., 2020).

Resource limitation can impact population growth rate regardless of additional anthropogenic disturbance. Stochastic Dynamic Programming models have been used to explore the impact declining prey species has on focal marine mammal predators (McHuron et al., 2023a; McHuron et al., 2023b). A Stochastic Dynamic Programming model determined that a decrease in walleye pollock availability increased the time and distance northern fur seal mothers had to travel offshore, which negatively impacted pup growth rate and wean mass, despite attempts to compensate with longer recovery time on land (McHuron et al., 2023b).

Prey is an important factor in long-term consequence models for many species of marine mammals. In disturbance models that predict habitat displacement or otherwise reduced foraging opportunities, populations are being deprived of energy dense prey or "high quality" areas which can lead to long-term impacts on fecundity and survival (Czapanskiy et al., 2021; Hin et al., 2019; McHuron et al., 2023a; New et al., 2013b).

Prey density limits the energy available for growth, reproduction, and survival. Some disturbance models indicate that the immediate decrease in a portion of the population (e.g., young lactating mothers) is not necessarily detrimental to a population, since as a result, prey availability increases and the population's overall improved body condition reduces the age at first calf (Hin et al., 2021).

The timing of a disturbance with seasonally available resources is important. If a disturbance occurs during periods of low resource availability, the population-level consequences are greater and occur faster than if the disturbance occurs during periods when resource levels are high (Hin et al., 2019). When resources are not evenly distributed, populations with cautious strategies and knowledge of resource variation have an advantage (Pirotta et al., 2020).

Even when modeled alongside several anthropogenic sources of disturbance (e.g., vessel strike, vessel noise, chemical contaminants, sonar), several species of marine mammals are most influenced by lack of prey (Czapanskiy et al., 2021; Murray et al., 2021). Some species like killer whales are especially sensitive to prey abundance due to their limited diet (Murray et al., 2021). The short-term energetic cost of eleven species of cetaceans and mysticetes exposed to mid-frequency active sonar was influenced more by lost foraging opportunities than increased locomotor effort during avoidance (Czapanskiy et al., 2021). Additionally, the model found that mysticetes incurred more energetic cost than odontocetes, even during mild behavioral responses to sonar. These results may be useful in the development of future Population Consequences of Multiple Stressors and Population Consequences of Disturbance models since they should seek to qualify cetacean health in a more ecologically relevant manner.

D.4.8.5 Harbor Porpoises and Non-Military Disturbance Consequences

Studies have investigated the potential consequences of fasting for harbor porpoises because their high metabolic rate may leave them especially vulnerable to disturbances that prevent them from feeding. Four stranded harbor porpoises were able to consume 85–100 percent of their daily food mass intake in a short time period with no physical problems, suggesting that they can compensate for periods of missed feeding if food is available (Kastelein et al., 2019c). Harbor porpoises are also capable of recovering from lost foraging opportunities, largely because of their varied diet, high foraging rates, and high prey capture success (Booth, 2019). By modeling their foraging behavior and known prey species and sizes, the porpoises' generalist feeding behavior, in most scenarios, would enable them to obtain more than 100 percent of their energetic needs through typical foraging behavior, and therefore would largely be robust to short-term disturbances to foraging.

Seasonality is an important predictor of disturbance for harbor porpoises. Movement and foraging behavior were modeled in seasons, and seismic activity in May had a much smaller impact on harbor porpoise health and reproduction, due to the porpoises having greater energy stores that time of year and females having already weaned their calves (Gallagher et al., 2021). In contrast, seismic surveys in September had a much greater impact due to lower energy reserves at that time, while females were lactating and possibly pregnant as well.

Different stressors and models have generated different long-term consequences within the same species. Even when high and frequent exposure levels are included, some harbor porpoise models result in few long-term consequences from sound exposure (e.g., wind farms, pile driving), but have costly results in others (e.g., pile driving, seismic surveys) (King et al., 2015). For example, the impact of noise from wind farms on harbor porpoises predicted that even when assuming a 10 percent reduction in population size if prey is impacted up to two days, the presence of ships and wind turbines did not deplete the population. Similarly, even under the worst case scenarios, King et al. (2015) model of wind farm impacts on harbor porpoises predicted less than a 0.5 percent decline in harbor porpoise populations. De Silva et al. (2014) analyzed the long-term impacts of a different stressor (pile driving and construction noise) on harbor porpoises and bottlenose dolphins. Despite including the extreme and unlikely assumptions that 25 percent of animals that received PTS would die, and that behavioral displacement from an area would lead to breeding failure, the model only found short-term impacts on the population size and no long-term effects on population viability. In contrast, Heinis et al. (2015) used the Population Consequences of Disturbance framework to estimate impacts from both pile driving and seismic exploration on harbor porpoises and found a 23 percent decrease in population size over six years, with an increased risk for further reduction with additional disturbance days. These seemingly contradictory results demonstrate that refinements to models need to be investigated to improve consistency and interpretation of model results.

D.4.8.6 Multiple Stressors and Cumulative Effects

Population consequences of disturbance models have been used to assess the impacts of multiple and recurring stressors. A marine mammal population that is already subject to chronic stressors like climate change will likely be more vulnerable to acute disturbances. Models that have looked at populations of cetaceans who are exposed to multiple stressors over several years have found that even one major chronic stressor (e.g., climate change, epizootic disease, oil spill) has severe impacts on population size. A layer of one or more stressor (e.g., seismic surveys) in addition to a chronic stressor (like an oil spill) can yield devastating impacts on a population. These results may vary based on species and location, as one population may be more impacted by chronic shipping noise, while another population may not. However, just because a population doesn't appear to be impacted by one chronic stressor (e.g., shipping noise), does not mean they aren't affected by others, such as climate change or disease (Reed et al., 2020). Recurring or chronic stressors can impact population abundance even when instances of disturbance are short and have minimal behavioral impact on an individual (Farmer et al., 2018a; McHuron et al., 2018b; Pirotta et al., 2019). Some changes to response variables like pup recruitment (survival to age one) aren't noticeable for several years, as the impacts on pup survival does not affect the population until those pups are mature but impacts to young animals will ultimately lead to population-wide declines. The severity of the repeated disturbance can also impact a population's long-term reproductive success. Scenarios with severe repeated disturbance (e.g., 95 percent probability of exposure, with 95 percent reduction in feeding efficiency) can severely reduce fecundity and calf survival, while a weaker disturbance (25 percent probability of exposure, with 25 percent reduction in feeding efficiency) had no population-wide effect on vital rates (Pirotta et al., 2019). An expanded version of the Population Consequences of Multiple Stressors framework in Figure D.4-7 would include multiple "exposure to stressor" buttons to signify the many stressors an individual and population faces, as well as multiple layers of physiological and behavioral responses per individual (National Academies of Sciences Engineering and Medicine, 2017).

The study that modeled an oil spill led to chronic declines in a sperm whale population over 10 years, and if models included even one more stressor (i.e., behavioral responses to air guns), the population declined even further (Farmer et al., 2018a). However, the amount of additional population decline due to acoustic disturbance depended on the way the dose-response of the noise levels were modeled. A single step-function led to higher impacts than a function with multiple steps and frequency weighting. In addition, the amount of impact from both disturbances was mediated when the metric in the model that described animal resilience was changed to increase resilience to disturbance (e.g., able to make up reserves through increased foraging).

Not all stressors have the same impact for all species and all locations. Another model analyzed the effect of a number of chronic disturbances on two bottlenose dolphin populations in Australia over 5 years (Reed et al., 2020). Results indicated that disturbance from fisheries interactions and shipping noise had little overall impact on population abundances in either location, even in the most extreme impact scenarios modeled. At least in this area, epizootic and climate change scenarios had the largest impact on population size and fecundity.

Recurring stressors can impact population abundance even when individual instances of disturbance are short and have minimal behavioral impact on an individual. A model on California sea lions introduced a generalized disturbance at different times throughout the breeding cycle, with their behavior response being an increase in the duration of a foraging trip by the female (McHuron et al., 2018b). Very short duration disturbances or responses led to little change, particularly if the disturbance was a single event, and changes in the timing of the event in the year had little effect. However, with even relatively short disturbances or mild responses, when a disturbance was modeled as recurring there were resulting reductions in population size and pup recruitment (survival to age one). Often, the effects weren't noticeable for several years, as the impacts on pup survival did not affect the population until those pups were mature.

D.4.8.7 PcoD Models as Tools for Management

PcoD models may also have application for species management. One model used for migrating humpback whale mother-calf pair responses to seismic surveys used both a forwards and backward approach (Dunlop et al., 2021). While a typical forwards approach can determine if a stressor would have population-level consequences, authors demonstrated that working backwards through a Population Consequences of Disturbance model can be used to assess the worst-case scenario for an interaction of a target species and stressor. This method may be useful for future management goals when appropriate data becomes available to fully support the model.

D.4.8.8 Long-Term Consequences on Navy Ranges

D.4.8.8.1 Blue Whales on Navy Ranges in Southern California

The U.S. Navy funds research on blue whale sonar disturbance on Navy ranges. Pirotta et al. (2018b) modeled one reproductive cycle of a female North Pacific blue whale, starting with leaving the breeding grounds off Baja California to begin migrating north to feeding grounds off California, and ending with her returning to the breeding grounds, giving birth, and lactating. They modeled this scenario with no disturbance and found 95 percent calf recruitment (the successful growth and weaning of a calf); under a "normal" environmental perturbation (El Niño-Southern Oscillation) there was a very small reduction in recruitment, and, under an "unprecedented" environmental change, recruitment was reduced to 69 percent. An intense, localized anthropogenic disturbance was modeled (although the duration of the event was not provided); if the animals were not allowed to leave the area, they did not forage, and recruitment dropped to 63 percent. However, if animals could leave the area of the disturbance, then there was almost no change to the recruitment rate. A weak but broader spatial disturbance, where foraging was reduced by 50 percent, caused only a small decrease in calf recruitment to 94 percent.

Pirotta et al. (2022a) investigated the potential long-term effects of changing environmental conditions and military sonar by modeling vital rates of Eastern North Pacific blue whales. Previous work from Pirotta et al. (2021) was used as a foundation for incorporating the best available science into the 2022 vital rate model. Using data and underlying models of behavioral patterns, energy budgets, body condition, contextual responses to noise, and prey resources, the model predicted female vital rates including survival (age at death), and reproductive success (number of female calves). The model simulation results showed that environmental changes were more likely to affect vital rates, "while the current regime of sonar activities was not " (Pirotta et al., 2022a). The case study used an annual sonar regime in Southern California Range Complex based on the description of the action in the Navy's 2018 Hawaii-Southern California Training and Testing EIS/OEIS. Additional military sonar scenarios were modeled, and only a ten-fold increase in sonar activity combined with a shift in geographical location to overlap with main feeding areas of blue whales resulted in a moderate decrease in lifetime reproductive success (Cohen's *d* = 0.47), but there was no effect on survival (Cohen's *d* = 0.05).

D.4.8.8.2 Beaked Whales on Navy Ranges

The Navy has funded sonar research on three instrumented ranges that contribute to understanding long-term effects on beaked whale populations exposed to sonar: Southern California Anti-Submarine Warfare Range, Atlantic Undersea Test and Evaluation Center, and the Pacific Missile Range Facility. Long-term impacts to sensitive beaked whale populations on Navy testing and training grounds is a heavily researched topic, and the residency on the range may play a role. Studies on the AUTEC instrumented range in the Bahamas have shown that some Blainville's beaked whales may be residents during all or part of the year in the area. Individuals may move off the range for several days during and following a sonar event but return within a few days (Joyce et al., 2019; McCarthy et al., 2011; Tyack et al., 2011).

A study by Benoit-Bird et al. (2020) demonstrated that differences in prey distribution could be a substantial factor for beaked whale habitat preference in the Bahamas. Photo-identification studies in the SOCAL Range Complex have identified approximately 100 individual goose-beaked whales, with 40 percent having been seen in one or more prior years and re-sightings up to seven years apart (Falcone & Schorr, 2014; Falcone et al., 2009). These results indicate long-term residency by individuals in an intensively used Navy training area, which may suggest a lack of long-term consequences from exposure to Navy training activities but could also be indicative of high-value resources that exceed the cost of remaining in the area. Long-term residency by itself does not mean there has been no impact on population growth rates and there are no data on the reproductive rates of populations inhabiting the Navy range area around San Clemente Island compared to beaked whales from other areas. In that regard however, results from photo-identification efforts can provide critically needed calving and weaning rate data for resident animals on the Navy's Southern California range. Three adult females that had been sighted with calves in previous years were again sighted in 2016, one of these was associated with her second calf, and a fourth female that was first identified in 2015 without a calf, was sighted in 2016 with a calf (Schorr et al., 2017). Resident females documented with and without calves from year to year will provide data on growth rate for this population.

Beaked whales may routinely move hundreds of kilometers as part of their normal pattern. While at least some beaked whales are residents of a particular area, more than three beaked whales in the SOCAL Range Complex have been documented traveling hundreds of kilometers after being tagged (Falcone & Schorr, 2012, 2014). Out of eight goose-beaked whales, five made journeys of approximately 250 km from their tag deployment location, and one of these five made an extra-regional excursion over 450 km south to Mexico and back again (Schorr et al., 2014).

D.4.8.8.3 Ongoing Research and Monitoring

The best assessment of long-term consequences from Navy training activities will be to monitor the populations over time within the Study Area. A U.S. workshop on Marine Mammals and Sound (Fitch et al., 2011) indicated a critical need for baseline biological data on marine mammal abundance, distribution, habitat, and behavior over sufficient time and space to evaluate impacts from human-generated activities on long-term population survival. The Navy has implemented comprehensive monitoring plans since 2009 for protected marine mammals on Navy ranges with the goal of assessing the impacts of training activities on marine species and the effectiveness of the Navy's mitigation measures. The results of this long-term monitoring are continually being compiled and analyzed for trends in occurrence or abundance over time (e.g., Martin et al., 2017).

Preliminary results of this analysis at Pacific Missile Range Facility off Kauai, Hawaii indicate no changes in detection rates for several species over the past decade, demonstrating that Navy activities may not be having long-term population-level impacts. This type of analysis can be expanded to the other Navy ranges, such as in the Pacific Northwest. Continued analysis of this 15-year dataset and additional monitoring efforts over time are necessary to fully understand the long-term consequences of exposure to military readiness activities.

It should be noted that, in all the population consequence models discussed above, many assumptions were made, and many input variables were unknown and so were estimated using data when available. It is not possible to estimate long-term or population-level effects from individual short-term behavioral responses alone.

D.5 REPTILES

This section describes general effects to reptiles from exposure to acoustic and explosive sources, including potential responses from species not present in the Study Area. Despite data gaps in the available literature (as mentioned throughout), the research synthesized here is considered best available science and are used to support the conclusions made in the Action Proponents impact analysis.

D.5.1 HEARING AND VOCALIZATION

Sea turtle ears are adapted for hearing underwater and in air, with auditory structures that may receive sound via bone conduction (Lenhardt et al., 1985), resonance of the middle ear cavity (Willis et al., 2013), or the standard tympanic middle ear path (Hetherington, 2008). In-water hearing in sea turtles is typically between 50 and 1,600 Hertz (Hz). Maximum hearing sensitivity is between 100 and 400 Hz, and sensitivity rapidly drops off at higher frequencies (Bartol & Ketten, 2006; Martin et al., 2012; Piniak et al., 2012b; Piniak et al., 2016). Sea turtles are also limited to low-frequency hearing in-air, with juveniles hearing between 50 and 800 Hz, with a maximum hearing sensitivity around 300–400 Hz (Bartol & Ketten, 2006; Piniak et al., 2016). Hearing abilities have primarily been studied with sub-adult, juvenile, and hatchling subjects in four sea turtle species, including green (Bartol & Ketten, 2006; Ketten & Moein-Bartol, 2006; Piniak et al., 2016; Ridgway et al., 1969; Yudhana et al., 2010), olive ridley (Bartol & Ketten, 2006), loggerhead (Bartol et al., 1999; Lavender et al., 2014; Martin et al., 2012), and leatherback (Piniak et al., 2012a). Only one study examined the auditory capabilities of an adult sea turtle (Martin et al., 2012); the hearing range of the adult loggerhead turtle was similar to other measurements of juvenile and hatchling sea turtle hearing ranges.

The role of underwater hearing in sea turtles is unclear. Sea turtles may use acoustic signals from their environment as guideposts during migration and as cues to identify their natal beaches (Lenhardt et al., 1983). However, they may rely more on other senses, such as vision and magnetic orientation, to interact with their environment (Avens, 2003; Lohmann & Lohmann, 2019; Narazaki et al., 2013; Putman et al., 2015). Hearing may also be used for intra-specific communication in water (Charrier et al., 2022) and in air, including hatching synchronization and nest emergence (Cook & Forrest, 2005; Ferrara et al., 2014; Ferrara et al., 2019; McKenna et al., 2019; Mrosovsky, 1972).

All best-available underwater sea turtle AEP and behavioral hearing threshold data from the scientific literature were considered to develop a composite sea turtle audiogram for underwater hearing (Figure D.5-1). An overview of the data used, and the methods to develop a composite sea turtle audiogram for underwater hearing are described in the *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase IV) technical report* (U.S. Department of the Navy, 2024a).

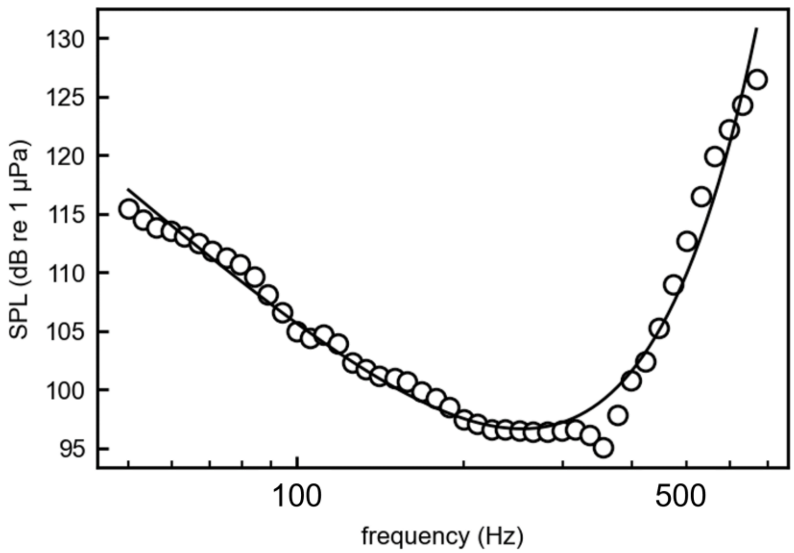


Figure D.5-1: Composite Audiogram used in Sea Turtle Criteria and Thresholds(U.S. Department of the Navy, 2024a)

Some in-air sounds have been recorded during nesting activities ashore, including belch-like sounds and sighs, exhale/inhales, gular pumps, and grunts by female leatherback turtles, and low-frequency pulsed and harmonic sounds by hawksbill, Olive Ridley, Kemp's Ridley, leatherback, and green sea turtle embryos in eggs and hatchlings (Cook & Forrest, 2005; Ferrara et al., 2014; Ferrara et al., 2019; McKenna et al., 2019; Mrosovsky, 1972). Underwater vocalizations from juvenile green turtles have been characterized as pulses, low amplitude calls, frequency modulated sounds, and squeaks (Charrier et al., 2022). Croaks and squeaks have components that are outside the known frequency bandwidth of green turtle hearing and may only be partially detectable (Charrier et al., 2022). These vocalizations were not associated with a specific behavior or the presence of another sea turtle, but there are similarities in vocalizations from freshwater turtles and hatchling Kemp's ridley turtles (Ferrara et al., 2019; Giles et al., 2009).

Snakes lack external and middle ear structures but retain a single ear bone, the columella auris (Hartline, 1971), which interacts with the inner ear. In snakes, the columella auris is connected to the lower jaw bone (Christensen et al., 2012; Hartline, 1971) which conducts vibrations (Hartline, 1971). Limited information on sea snake hearing currently exists, however, they have been shown to respond to underwater sounds below 600 Hz with highest sensitivity at 60 Hz, and from 300-500 Hz {Chapuis, 2019, `#23447}. Vibrations from low-frequency sounds are likely used to detect approaching predators and prey (Hartline, 1971). Sea snakes may also use other senses for interacting with their environment. For example, turtle-headed sea snakes (*Emydocephalus annulatus*) rely primarily on scent for chemical cueing of prey (Shine et al., 2004). In addition, scales on the head and body of sea snakes have mechanoreceptors which may assist in detecting low-frequency vibrations {Chapuis, 2019, `#23447}{Crowe-Riddell, 2019, `#23126}. At present, no information has been found indicating that sea snakes vocalize.

Sea turtles and sea snakes have similar hearing capabilities and likely usage. Therefore, the types of impacts to sea snakes are assessed to be comparable to those for sea turtles.

D.5.2 Hearing Loss and Auditory Injury

A Working Group organized under the ANSI-Accredited Standards Committee S3, Subcommittee 1, Animal Bioacoustics, developed sound exposure guidelines for fishes and sea turtles (Popper et al., 2014), hereafter referred to as the *ANSI Sound Exposure Guideline Technical Report*. The guidelines do not include numeric sound exposure thresholds for auditory effects on sea turtles rather, they qualitatively estimate that sea turtles are less likely to incur TTS or AINJ with increasing distance from various sound sources. Sea turtle hearing is most sensitive around 100–400 Hz in-water and is limited over 1 kHz (Bartol & Ketten, 2006; Martin et al., 2012; Piniak et al., 2012b; Piniak et al., 2016). Therefore, sound exposures from most mid-frequency and all high-frequency sound sources are not anticipated to affect sea turtle hearing, and sea turtles are likely only susceptible to auditory impacts when exposed to very high levels of sound within their limited hearing range. No studies have measured TTS or AINJ in sea turtles, however, TTS in freshwater turtles has been examined {Salas, 2024, `#19190;Salas, 2024, `#23444;Salas, 2023, `#19358}. Onset values of TTS for freshwater turtles (Salas et al., 2023b, 2024) were extrapolated to determine a TTS onset level for non-impulsive sources in sea turtles (U.S. Department of the Navy, 2024a, In progress.). Consistent with methods from prior analyses, (U.S. Department of the Navy, 2017b) TTS onset levels for non-impulsive sources were used to determine AINJ for non-impulsive sound sources, and onset levels for impulsive sources (U.S. Department of the Navy, 2024a, In progress.).

D.5.3 Masking

Reptiles likely use their hearing to detect broadband low-frequency sounds in their environment so the potential for masking would be limited to sound exposures that have similar characteristics (i.e., frequency, duration, and amplitude). Continuous and near-continuous human-generated sounds that have a significant low-frequency component, are not brief, and are of sufficient received level, are most likely to result in masking (e.g., proximate vessel noise and high-duty cycle or continuous active sonar). Other intermittent, short-duration sound sources with low-frequency components (e.g., air guns, pile driving, aircraft noise, weapons noise, and explosives) would have limited potential for masking.

Because reptiles may rely primarily on senses other than hearing for interacting with their environment, any effect of masking may be mediated by reliance on other environmental inputs.

D.5.4 Behavioral Reactions

Behavioral responses fall into two major categories: Alterations in natural behavioral patterns and avoidance. These types of reactions are not mutually exclusive, and reactions may be combinations of behaviors or a sequence of behaviors. The response of a sea turtle to an anthropogenic sound would likely depend on the frequency, duration, temporal pattern, and amplitude of the sound as well as the animal's prior experience with the sound and the context in which the sound is encountered (i.e., what the animal is doing at the time of the exposure) (Ellison et al., 2011; Southall et al., 2021; Wartzok et al., 2003). Distance from the sound source and whether it is perceived as approaching or moving away may also affect a sea turtle's response.

In the *ANSI Sound Exposure Guideline Technical Report* (Popper et al., 2014), qualitative risk factors were developed to assess the potential for sea turtles to respond to various underwater sound sources. The guidelines state that there is a low likelihood that sea turtles would respond within tens of meters of low-frequency sonars, and that it is highly unlikely that sea turtles would respond to mid-frequency sources. The risk that sea turtles would respond to other broadband sources, such as shipping, is considered high within tens of meters of the sound source, but moderate to low at farther distances.

D.5.4.1 Behavioral Reactions to Sonar and Other Transducers

Studies of reptile responses to sonar and other transducers are limited and all data are from studies with sea turtles. Lenhardt (1994) used very low-frequency vibrations (less than 100 Hz) coupled to a shallow tank to elicit swimming behavior responses by two loggerhead sea turtles in which turtles swam to the surface and remained at the surface or slightly submerged. The limitations of conducting acoustic experiments in shallow tanks are discussed in Section D.1.5, Acoustic Propagation in Small Tanks. Watwood et al. (2016) tagged green sea turtles with acoustic transponders and monitored them using acoustic telemetry arrays in Port Canaveral, Florida. Sea turtles were monitored before, during, and after a routine pier-side submarine sonar test that utilized typical source levels, signals, and duty cycle. The authors concluded that no significant long-term displacement was exhibited by the sea turtles in this study. The authors note that Port Canaveral is an urban marine habitat and that resident sea turtles may be less likely to respond than naïve populations.

Kastelein et al. (2023) exposed two green and two hawksbill sea turtles to a wide variety of potential acoustic deterrent signals (> 200 Hz) including Helicopter Long-Range Active Sonar (HELRAS) down sweeps (1.3 – 1.44 kHz). The authors concluded that no behavioral responses were observed to the HELRAS, pure tones, impulsive sounds, or killer whale vocalizations, at levels of approximately 173 dB re 1 µPa. Behavioral responses were observed to eighteen different sounds with various spectro-temporal characteristics, duty cycles and received levels. Of those, four sound types with Navy-relevant signal characteristics (frequency modulated and upsweep). However, no consistent relationship between signal level and behavioral response was observed, and contextual factors appeared to explain some of these responses. The baseline behavioral state of the sea turtle appeared to influence the likelihood of a response, with bottom-resting sea turtles exhibiting little to no responses. The reverberant, shallow environment of the testing pool, minimal controls in the experimental design, and absence of behavioral responses to impulsive sounds suggests that the results of this study should be interpreted with caution, and do not necessitate any changes to the criterion for sonar.

According to the qualitative risk factors developed in the *ANSI Sound Exposure Guideline Technical Report* (Popper et al., 2014), the likelihood of sea turtles responding to low- and mid-frequency sonar is low and highly unlikely, respectively. Based on the limited behavioral response data discussed above, behavioral responses to non-impulsive sounds could consist of temporary avoidance, increased swim speed, or no observable response.

D.5.4.2 Behavioral Reactions to Vessel Noise

There is limited information on reptile behavioral responses to vessel noise. Diaz et al. (2023) quantified the behavioral responses of free-ranging green turtles to vessel noise using audio, video, and positional data from devices mounted to the carapace. Data were collected in the presence and absence of vessel noise while turtles were either traveling or resting on the sea floor. During exposures to vessel noise, existing behaviors were amplified, and the time spent traveling or at the sea floor increased. In addition, more time was spent scanning during traveling when vessel noise was present, which may indicate increased vigilance to detect potential threats. This supports the findings from Hazel et al. (2007) in which turtles avoided vessels more quickly when there was good visibility. In contrast, the amount of time spent scanning while at the sea floor did not significantly increase when vessel noise was present. While at the sea floor vessels may not be perceived as an immediate threat or vessel noise may not be detectable.

Based on the limited behavioral response data discussed above, behavioral responses to vessel noise could include amplification of existing behaviors, increased vigilance, or no observable response.

D.5.4.3 Behavioral Reactions to Aircraft Noise

Behavioral reactions due to aircraft noise, including hovering helicopters, are likely to be brief and minor, if they occur at all. Reptile reactions to aircraft noise have not been studied like marine mammals. For marine mammals, aircraft noise would cause only small temporary changes in behavior. Since reptile hearing is less sensitive than marine mammals, conservatively, it is likely that reptiles could exhibit temporary changes in behavior to aircraft noise as well.

D.5.4.4 Behavioral Reactions to Impulsive Sound Sources

There are limited studies of reptile responses to sounds from impulsive sound sources, and all data come from sea turtles exposed to seismic air guns. These exposures consist of multiple air gun shots, either in close proximity or over long durations, so it is likely that observed responses may over-estimate responses to single or short-duration impulsive exposures. Studies of responses to air guns are used to inform reptile responses to other impulsive sounds (e.g., weapon noise and explosions).

O'Hara and Wilcox (1990) attempted to create a sound barrier at the end of a canal using seismic air guns. They reported that loggerhead turtles kept in a 300 m by 45 m enclosure in a 10-m deep canal and maintained a minimum standoff range of 30 m from air guns fired simultaneously at intervals of 15 seconds with strongest sound components in the 25–1,000 Hz frequency range. McCauley et al. (2000a) estimated that the received SPL at which turtles avoided sound in the O'Hara and Wilcox (1990) experiment was 175–176 dB re 1 µPa.

Moein Bartol et al. (1995) investigated the use of air guns to repel juvenile loggerhead sea turtles from hopper dredges. Sound frequencies of the air guns ranged from 100 to 1,000 Hz at three source SPLs: 175, 177, and 179 dB re 1 µPa at 1 m. The turtles avoided the air guns during the initial exposures (mean range of 24 m), but additional exposures on the same day and several days afterward did not elicit avoidance behavior that was statistically significant. They concluded that this was likely due to habituation.

McCauley et al. (2000a) exposed a caged green and a caged loggerhead sea turtle to an approaching-departing single air gun to gauge behavioral responses. The trials showed that above a received SPL of 166 dB re 1 µPa, the turtles noticeably increased their swimming activity compared to nonoperational periods, with swimming time increasing as air gun SPLs increased during approach. Above 175 dB re 1 µPa, behavior became more erratic, possibly indicating the turtles were in an agitated state. The authors noted that the point at which the turtles showed more erratic behavior and exhibited possible agitation would be expected to approximate the point at which active avoidance to air guns would occur for unrestrained turtles.

No obvious avoidance reactions by free-ranging sea turtles, such as swimming away, were observed during a multi-month seismic survey using air gun arrays, although fewer sea turtles were observed when the seismic air guns were active than when they were inactive (Weir, 2007). Weir (2007) noted that sea state and the time of day affected both air gun operations and sea turtle surface basking behavior, making it difficult to draw conclusions from the data. However, DeRuiter and Doukara (2012) noted several possible startle or avoidance reactions to a seismic air gun array in the Mediterranean by loggerhead turtles that had been motionlessly basking at the water surface.

Based on the limited behavioral response data discussed above, reptile behavioral responses to impulsive sounds could consist of temporary avoidance, increased swim speed, or changes in depth; or there may be no observable response.

D.5.5 Physiological Response

A stress response is a suite of physiological changes meant to help an organism mitigate the impact of a stressor. If the magnitude and duration of the stress response is too great or too long, then it can have negative consequences to the animal (e.g., decreased immune function, decreased reproduction). Physiological stress is typically analyzed by measuring stress hormones, other biochemical markers, or vital signs. Physiological stress (e.g., corticosterone, glucose, total white blood cell count, and heterophil/lymphocyte ratio) has been measured for sea turtles during nesting (Arango et al., 2022; Flower et al., 2015; Valverde et al., 1999; Vasquez-Bultron et al., 2021), capture and handling (Flower et al., 2015; Gregory & Schmid, 2001; Usategui-Martin et al., 2021), transport (Hunt et al., 2019; Hunt et al., 2020), rehabilitation (Caliani et al., 2019), and when caught in entanglement nets (Hoopes et al., 2000; Miguel et al., 2020; Snoddy et al., 2009) and trawls (Stabenau et al., 1991). However, the stress caused by acoustic exposure has not been studied for sea turtles. Therefore, the stress response in sea turtles in the Study Area due to acoustic exposures is considered to be consistent with general knowledge about physiological stress responses described in the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities.

Marine animals naturally experience stressors within their environment and as part of their life histories. Changing weather and ocean conditions, exposure to diseases and naturally occurring toxins, lack of prey availability, social interactions with members of the same species, nesting, and interactions with predators all contribute to stress (Atkinson et al., 2015). Anthropogenic sound-producing activities have the potential to provide additional stressors beyond those that naturally occur (Fair et al., 2014; Meissner et al., 2015; Rolland et al., 2012).

Due to the limited information about acoustically induced stress responses for reptiles, the Action Proponents conservatively assume in its effects analysis that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

D.5.6 Direct Injury due to Sonar

The high peak pressures close to some non-impulsive underwater sound sources may be injurious, although there are no reported instances of injury to sea turtles caused by these sources. Lacking any data on non-auditory sea turtle injuries due to sonar, *ANSI Sound Exposure Guideline Technical Report* (Popper et al., 2014) estimated the risk to sea turtles from low-frequency sonar to be low and mid-frequency sonar to be non-existent. Additionally, sea turtle carapaces (i.e., shells) may protect against non-auditory injury due to exposures to high peak pressures (Popper et al., 2014).

Mechanisms for non-auditory injury due to acoustic exposure have been hypothesized for diving breath-hold animals. Acoustically induced bubble formation, rectified diffusion, and acoustic resonance of air cavities are considered for their similarity to pathologies observed in marine mammals stranded coincident with sonar exposures but were found to not be likely causal mechanisms, and findings are applicable to reptiles.

Nitrogen decompression due to modifications to dive behavior in response to sonar exposures has never been observed in sea turtles. Sea turtles are thought to deal with nitrogen loads in their blood and other tissues, caused by gas exchange from the lungs under conditions of high ambient pressure during diving, through anatomical, behavioral, and physiological adaptations (Lutcavage & Lutz, 1997). Although diving sea turtles experience gas supersaturation, gas embolism has only been observed in sea turtles bycaught in fisheries, including loggerhead sea turtles (Garcia-Parraga et al., 2014), as well as leatherback, green, and olive ridley sea turtles (Crespo-Picazo et al., 2020). Therefore, nitrogen decompression due to changes in diving behavior in response to sonar exposures is not considered a potential consequence to diving reptiles.

D.5.7 Direct Injury due to Explosives

Data on observed injuries to reptiles from explosions is generally limited to animals found following explosive removal of offshore structures (Viada et al., 2008), which can attract reptiles for feeding or shelter (Klima et al., 1988; Viada et al., 2008). Klima et al. (1988) observed a turtle mortality subsequent to an oil platform removal blast, although sufficient information was not available to determine the animal’s exposure. Klima et al. (1988) also placed small sea turtles (less than 7 kg) at varying distances from piling detonations. Some of the turtles were immediately knocked unconscious or exhibited vasodilation (i.e., expansion of blood vessels), but others at the same exposure distance exhibited no effects. Vasodilation was present around the throat and flippers for 2-3 weeks and the increase in blood flow helped to repair damaged cells and tissue. Unconsciousness renders a turtle more susceptible to predation and may result in sinking to the bottom. Although resting turtles can remain submerged for hours, the effects of submergence on stunned turtles are unknown. These data also verified that explosions could result in both near- and far- field injuries to turtles.

Incidental injuries to sea turtles due to military explosions have been documented in a few instances. In one incident, a single 1,200 lb. trinitrotoluene (TNT) underwater charge was detonated off Panama City, Florida, in 1981. The charge was detonated at a mid-water depth of 120 ft. Although details are limited, the following were recorded: at a distance of 500–700 ft., a 400 lb. sea turtle was killed; at 1,200 ft., a 200 to 300 lb. sea turtle experienced “minor” injury; and at 2,000 ft. a 200 to 300 lb. sea turtle was not injured (O'Keeffe & Young, 1984). In another incident, two “immature” green sea turtles (size unspecified) were killed when 100 to 150 ft. away from detonation of 20 lb. of C-4 in a shallow-water environment. This illustrates that the likelihood and types of injuries from underwater explosives depends on the charge size, the geometry of the exposure (distance to the charge, depth of the animal and the charge), and the size of the animal.

D.5.8 Long-Term Consequences

For reptiles present in the Study Area, long-term consequences to individuals and populations due to acoustic exposures have not been studied. For this analysis it is assumed that long term-consequences to reptiles are consistent with general knowledge about long-term consequences to other marine species.

Long-term consequences to reptile populations due to disturbances, whether anthropogenic or environmental, are difficult to assess. Linking non-lethal effects on individuals to changes in population growth rates requires long-term data, which is lacking for many populations. The long-term consequences of hearing loss, chronic masking, and short-term or chronic physiological stress are especially difficult to predict because of the different factors experienced by individual animals, such as context of stressor exposure, underlying health conditions, and other environmental or anthropogenic stressors.

An important variable to consider is duration of disturbance. Severity scales used to assess behavioral responses to acute sound exposures are not appropriate to apply to sustained or repeated (chronic) exposures, as the focus has shifted from the immediate impacts to an individual to the health of a population over time (Southall et al., 2021). For example, short-term costs experienced over the course of a week by an otherwise healthy individual may be recouped over time after exposure to the stressor ends. These short-term costs would be unlikely to result in long-term consequences to that individual or to that individual's population. Comparatively, long-term costs accumulated by otherwise healthy individuals over an entire season, year, or throughout a life stage would be less easily recouped and more likely to result in long-term consequences to that individual or population.

Reptiles exposed to frequent or intense human activities may leave the area, habituate to the activity, or tolerate the disturbance and remain in the area (Wartzok et al., 2003). Highly resident or localized populations may also stay in an area of disturbance because the cost of displacement may be higher than the cost of remaining (Forney et al., 2017). An apparent lack of response (e.g., no displacement or avoidance of a sound source) may not necessarily mean there is no cost to the individual or population, as some resources or habitats may be of such high value that animals may choose to stay, even when experiencing the consequences of stress, masking, or hearing loss (Forney et al., 2017).

Longer term displacement can lead to changes in abundance or distribution patterns of the species in the affected region (Bejder et al., 2006b; Blackwell et al., 2004; Teilmann et al., 2006). Predicting population trends or long-term displacement patterns due to anthropogenic disturbance is challenging due to limited information and survey data for many species over sufficient temporal and spatial scales, as well as a full understanding of how other factors, such as oceanographic oscillations and climate change, affect presence.

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Appendix E Explosive and Acoustic Analysis Report

Acoustic and Explosive Effects Analysis for Marine Mammals, Reptiles, and Fishes in the Hawaii - California Training and Testing Study Area

Version 4 – November 2024

Prepared By: Bioacoustic Analysis and Applied Research Team
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Acronyms and Abbreviations

Acronym	Definition
µPa	microPascal
AINJ	Auditory Injury
BEH	Behavioral Response
BIA	Biologically Important Area
dB	decibel
EIS	Environmental Impact Statement
EXWC	Naval Facilities Engineering & Expeditionary Warfare Center
HCTT	Hawaii-California Training and Testing
HF	High Frequency (hearing group)
HSTT	Hawaii-Southern California Training and Testing
Hz	hertz
INJ	Non-Auditory Injury
kHz	kilohertz
LF	Low Frequency (hearing group)
LOA	Letter of Authorization
MMPA	Marine Mammal Protection Act
MORT	Mortality
NAEMO	Navy Acoustic Effects Model
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NAVWAR	Naval Information Warfare Systems Command
Navy	U.S. Department of the Navy
NBVC	Naval Base Ventura County
NEPA	National Environmental Policy Act
NM	Nautical Mile
NM^2	Square Nautical Miles
NMFS	National Marine Fisheries Service
NMSDD	Navy Marine Species Density Database

Acronym	Definition
NOCAL	Northern California
OCA	Otariids and Other Marine Carnivores In Air (hearing group)
OCW	Otariids and Other Marine Carnivores in Water (hearing group)
OEIS	Overseas Environmental Impact Statement
ONR	Office of Naval Research
OPAREA	Operating Area
PCA	Phocid In Air (hearing group)
PCW	Phocid In Water (hearing group)
PMRF	Pacific Missile Range Facility
PMSR	Point Mugu Sea Range
PTS	Permanent Threshold Shift
rms	Root-mean-square
SCI	San Clemente Island
SEL	Sound Exposure Level
SINKEX	Sinking Exercise
SNI	San Nicolas Island
SOAR	Southern California Anti-Submarine Warfare Range
SOCAL	Southern California
SPL	Sound Pressure Level
SWTR	Shallow Water Training Range
TR	Technical Report
TTS	Temporary Threshold Shift
UAV	Unmanned Aerial Vehicle
U.S.	United States
UUV	Unmanned Underwater Vehicle
VHF	Very High Frequency (hearing group)
VLF	Very Low Frequency (hearing group)
W-	Warning Area

Acronym	Definition
USCG	U.S. Coast Guard
USAF	U.S. Air Force
USMC	U.S Marine Corps

1 INTRODUCTION

This analysis presents impacts on marine species due to acoustic and explosive stressors under a maximum year of military readiness activities conducted at sea under the Hawaii-California Training and Testing (HCTT) Proposed Action. There are two Action Alternatives in HCTT: Alternative 1 and Alternative 2. Alternative 1 is the Preferred Alternative and reflects a representative year of training and testing to account for the natural fluctuations of training cycles, testing programs, and deployment schedules that generally limit the maximum level of training and testing from occurring for the reasonably foreseeable future. Alternative 2 reflects the maximum number of training activities that could occur within a given year and assumes that the maximum level of activity would occur every year over a seven-year period. However, both action alternatives assume the same level of activity in a maximum year.

1.1 INFORMATION REFERENCED IN THIS ANALYSIS

The acoustic and explosive impact analysis provided here relies on information presented in other sections and appendices of this EIS, and relevant technical reports. The following lists contain abbreviated names for each of these supporting sections and briefly describes the content therein. The impact analysis refers to these supporting sections using the italicized names noted here.

Sections that provide details and descriptions of the Proposed Action include the following:

- The *Proposed Activities* section in Section 2.3 (Proposed Activities) of this Draft EIS/OEIS provides the number of activities and the locations they would occur.
- The *Activity Descriptions* section in Appendix A (Activity Descriptions) of this Draft EIS/OEIS describes for each activity the following information: the primary mission area, details of the activity, typical components, acoustic/explosive bin categories, where they would occur, and any applicable mitigation measures.
- The *Acoustic Stressors* section in Sections 3.0.3.3.1 (Acoustic Stressors) and 3.0.3.3.2 (Explosive Stressors) of this Draft EIS/OEIS describes the general categories and characteristics of each acoustic substressor and explosive, along with their general use and quantity (counts or hours, as applicable) of annual and seven-year total use. Information on characteristics of vessel, aircraft, and weapons noise produced during training and testing activities can be found in Section 3.0.3.3 (Identifying Stressors for Analysis) of this Draft EIS/OEIS.
- The *Vessel Movements* data in Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors) of this HCTT Draft EIS/OEIS quantifies the vessel activity in each location in the Study Area, which is also relevant to where vessel noise would be generated in the Study Area.
- The *Munitions* data in Section 3.0.3.3.4 (Physical Disturbance and Strike Stressors) of this Draft EIS/OEIS quantifies the number of non-explosive practice munitions and the number of explosives that may result in fragments at each location in the Study Area, which are also relevant to where weapon noise (other than noise due to in-water explosives) would be generated in the Study Area.

Sections that provide general background information are listed below:

- The *Marine Mammal Background* sections in Section 3.7.2 (Affected Environment) and Appendix C (Biological Resources Supplemental Information) of this Draft EIS/OEIS describe species present in the Study Area; general biology, ecology, and status of each species; and descriptions of critical habitat, and Biologically Important Areas where applicable.

- The *Reptile Background* sections in Section 3.8.2 (Affected Environment) and Appendix C (Biological Resources Supplemental Information) of this Draft EIS/OEIS describe the species present in the Study Area; general biology, ecology, and status of each species; and descriptions of critical habitat, where applicable.
- The *Fishes Background* sections in Section 3.6.2 (Affected Environment) and Appendix C (Biological Resources Supplemental Information) of this Draft EIS/OEIS describe the species present in the Study Area; general biology, ecology, and status of each species; and descriptions of critical habitat, where applicable.
- The *Acoustic Primer* section in Appendix D (Acoustic and Explosive Effects Supporting Information; Section D.1, Acoustic and Explosive Concepts/Primer) of this Draft EIS/OEIS describes the basic concepts of sound and explosive energy transmission underwater and in air and introduces how animals perceive sound. The *Acoustic Primer* also describes acoustic metrics used in this analysis. Unless otherwise stated, sound pressure levels (SPL) in this analysis are root-mean-square (rms) values (see the *Acoustic Primer* section entitled Sound Metrics).
- The *Acoustic Habitat* section in Appendix D (Acoustic and Explosive Effects Supporting Information; Section D.2, Acoustic Habitat) of this Draft EIS/OEIS describes natural and anthropogenic sources that contribute to the ambient noise within the Study Area.
- The *Marine Mammal Acoustic Background* section in Appendix D (Acoustic and Explosive Effects Supporting Information; Section D.8, Marine Mammals) of this Draft EIS/OEIS summarizes the best available science on impacts on marine mammals from exposure to acoustic and explosive stressors.
- The *Reptile Acoustic Background* section in Appendix D (Acoustic and Explosive Effects Supporting Information; Section D.9, Reptiles) of this Draft EIS/OEIS summarizes the best available science on impacts on reptiles from exposure to acoustic and explosive stressors.
- The *Fishes Acoustic Background* section in Appendix D (Acoustic and Explosive Effects Supporting Information; Section D.7, Fishes) of this Draft EIS/OEIS summarizes the best available science on impacts on fishes from exposure to acoustic and explosive stressors.

Technical reports (TR) and analyses that provide details on the quantitative process and show specific data inputs to the models (all are available for download at https://www.nepa.navy.mil/HCTTeis/) are listed below:

- The *Quantitative Analysis TR* refers to the technical report titled *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing* (U.S. Department of the Navy, 2024b), which describes the modeling methods used to quantify impacts on marine mammals and sea turtles from exposure to sonar, air guns, and explosives. Impacts due to pile driving were modeled outside of the Navy Acoustic Effects Model (NAEMO) using a static area-density model and are also described in this technical report.
- The *Criteria and Thresholds TR* refers to the technical report titled *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase IV) (U.S. Department of the Navy, 2024a)*, which describes the development of criteria and thresholds used to predict impacts on marine mammals and sea turtles.

- The *Density TR* refers to the technical report titled *U.S. Navy Marine Species Density Database Phase IV for the Hawaii-California Training and Testing Study Area* (U.S. Department of the Navy, 2024c), which describes the spatial density distributions for each species or stock in the Study Area. The density models have been updated with new data since the prior analysis. The appendix to the density technical report includes figures showing the change in spatial density for each species since the prior analysis.
- The *Dive Profile and Group Size TR* refers to the technical report titled *Dive Distribution and Group Size Parameters for Marine Species Occurring in the U.S. Navy's Atlantic and Hawaii-California Training and Testing Study Areas* (Oliveira et al., 2024), which describes the dive profile and group size for each species. There are no substantive changes from the prior analysis.
- The *Pile Driving Analysis* shows the quantitative analysis for predicting impacts on marine mammals from pile driving. This is included in Appendix E of this Draft EIS/OEIS.

Mitigation information includes the following:

- The *Mitigation* section refers to Sections 5.6.1 (Mitigation Specific to Acoustic Stressors, Explosives, and Non-Explosive Ordnance), Section 5.6.2 (Mitigation Specific to Vessels, Vehicles, Deployment of Nets, and Towed In-Water Devices), and Section 5.7 (Geographic Mitigation) of this Draft EIS/OEIS, which describes the actions taken to avoid, reduce, or minimize potential impacts from acoustic and explosive stressors.

1.2 Changes from Prior Analyses

Changes in the predicted acoustic impacts on protected species since the Navy's 2018 Hawaii-Southern California Training and Testing (HSTT) and 2022 Point Mugu Sea Range (PMSR) analyses are primarily due to the following:

- Updates to data on marine mammal and reptile presence, including estimated density of each species or stock (number of animals per unit area), group size, and depth distribution. Any substantial changes that are affecting the quantified impacts in this analysis are discussed for each species or stock below. For additional details, including maps showing the relative density changes between this analysis and the prior analysis for this Study Area, see the *Density TR* and *Dive Profile TR*.
- Updates to criteria used to determine if an exposure to sound or explosive energy may cause auditory effects, non-auditory injuries, and behavioral responses. The changes in impact thresholds between this analysis and the prior analysis in the Study Area are shown in the applicable sections below. For additional details, see the technical report *Criteria and Thresholds TR*.
- Revisions to the modeling of acoustic effects due to proposed sound-producing activities in NAEMO. An overview of notable changes is provided in relevant sections below. For additional details, see the technical report *Quantitative Analysis TR*.
- Changes in the Study Area. In addition to areas previously included in the HSTT and PMSR analyses, the HCTT Study Area includes other areas off California including an expanded Southern California (SOCAL) Range Complex; new testing sea space between; the Northern California [NOCAL] Range Complex; areas along the Southern California coastline from approximately Dana Point to Port Hueneme; and four amphibious approach lanes providing California land access from NOCAL and

PMSR. Additional information on the expanded Study Area is in Chapter 2 (Description of Proposed Action and Alternatives) of the HCTT EIS/OEIS.

- Change in the proposed action. This report does not rely on the prior analyses of impacts for HSTT and PMSR. However, significant changes in the acoustic and explosive substressors used in training and testing activities that are relevant to understanding the predicted impacts on species under this proposed action compared to prior actions are noted in the analysis of each substressor.

2 IMPACTS ON MARINE MAMMALS FROM ACOUSTIC AND EXPLOSIVE STRESSORS

This analysis is presented as follows:

- The impacts that would be expected due to each type of acoustic stressor and explosives used in the Proposed Action are described in Section 2.1 (Impacts due to each Acoustic Substressor and Explosives).
    - Incidental take as defined under the Marine Mammal Protection Act (MMPA) is anticipated due to the following substressors: sonars and other transducers, air guns, pile driving, and explosives. Incidental take of ESA-listed marine mammals is anticipated due to sonars and other transducers, air guns, and explosives.
    - The following substressors are not anticipated to result in incidental take: vessel noise, aircraft noise, and weapons noise.
    - Impacts on hauled-out pinnipeds due to land-based launches at PMSR and the Pacific Missile Range Facility (PMRF) are assessed separately.
- The approach to modeling and quantifying impacts for stressors that may cause injury, auditory effects, or significant behavioral responses is summarized in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors).
- The approach to assessing the significance of responses for both individuals and populations is described in Section 2.3 (Assessing Impacts on Individuals and Populations).
- Impacts on individual species (stocks) in the Study Area, including predicted instances of harm or harassment, are presented in Section 2.4 (Species Impact Assessments). Tables summarizing quantified impacts due to each substressor that correspond to each request for a Letter of Authorization under the MMPA are presented at the end of Section 2.4 (Species Impact Assessments).
- Ranges to effects for each modeled sub-stressor are shown in Section 2.5 (Ranges to Effects).

2.1 IMPACTS DUE TO EACH ACOUSTIC SUBSTRESSOR AND EXPLOSIVES

Assessing whether a sound may disturb or injure a marine mammal involves understanding the characteristics of the acoustic sources, the marine mammals that may be present in the vicinity of the sources, and the effects that sound may have on the physiology and behavior of those marine mammals. Although it is known that sound is important for marine mammal communication, navigation, and foraging (National Research Council, 2003, 2005), there are many unknowns in assessing impacts, such as the potential interaction of different effects and the significance of responses by marine mammals to sound exposures (Nowacek et al., 2007; Southall et al., 2007; Southall et al., 2021b). Many other factors besides just the received level of sound may affect an animal's reaction, such as the duration of the sound-producing activity, the animal's physical condition, prior experience with the sound, activity at the time of exposure (e.g., feeding, traveling, resting), the context of the exposure (e.g., in a semi-enclosed bay vs. open ocean), and proximity of the animal to the source of the sound. The *Marine Mammal Acoustic Background* section summarizes what is currently known about effects to marine mammals from all acoustic substressors and explosives. That section cites the best available science that is relied on for this impact assessment.

In this analysis, impacts are categorized as mortality, non-auditory injury, auditory injury (AINJ, including permanent threshold shift [PTS] and auditory neural injury), temporary hearing loss (temporary threshold shift [TTS]), other physiological response (including stress), masking (occurs when a noise interferes with the detection, discrimination, or recognition of other sounds), and behavioral responses. These effects are defined and explained in the *Acoustic Primer* and the *Marine Mammal Acoustic Background* section. An "exposure" occurs when the received sound level is above the background ambient noise level within a similar frequency band; not all exposures are perceivable or result in impacts.

2.1.1 Impacts from Sonars and Other Transducers

Sonars and other transducers (collectively referred to as sonars in this analysis) emit sound waves into the water to detect objects, safely navigate, and communicate. Sonars are considered non-impulsive and vary in source level, frequency, duration (the total time that a source emits sound including any silent periods between pings), duty cycle (the portion of time a sonar emits sound when active, from infrequent to continuous), beam characteristics (narrow to wide, directional to omnidirectional, downward or forward facing), and movement (stationary or on a moving platform). Additional characteristics and occurrence of sonars used under the Proposed Action are described in the *Acoustic Stressors* and *Activity Descriptions* sections.

Although sonar use could occur throughout the Study Area, sonar use would typically occur within Navy training ranges, Navy testing ranges, associated inshore range locations, and specified ports and piers identified in the *Proposed Activities* section. Activities using sonar range from single source, limited duration events to multi-day events with multiple sound sources on different platforms. The types of sonars and the way they are used differ between primary mission areas. This in turn influences the potential for impacts on exposed marine mammals.

- Anti-submarine warfare typically relies on relatively high source level, mid-frequency sources including MF1 hull-mounted sonar, which is used on Navy combatant vessels such as destroyers. Most anti-submarine warfare sonars use mid-frequency ranges (1–10 kilohertz [kHz]), and some use low-frequency ranges (< 1 kHz). Most of these sonar signals are limited in the temporal, frequency, and spatial domains. The duration of most individual sounds is short, lasting up to a few seconds each. Systems typically operate with low-duty cycles for most tactical sources, but some systems may operate nearly continuously or with higher duty cycles. The MF1 hull-mounted sonar is the predominant vessel-based anti-submarine warfare sonar. It nominally operates at 3 kHz with a source level of 235 decibels (dB) re 1 microPascal (μPa) at 1 meter (m), pinging every 50 seconds. Due to their high source levels and low transmission loss (compared to higher frequency sources), anti-submarine warfare sonar sources have the largest zones of effects. The duration and duty cycle of different sources can vary greatly, from very low duty cycle submarine sonars that infrequently emit single pings, to helicopter dipping sonars that are active for minutes, to continuously active sources on some vessels. Sonar on torpedoes would be higher frequency and used for shorter periods of time. Most anti-submarine warfare activities would occur in the SOCAL Range Complex and the Hawaii Range Complex. Compared to the prior analysis, the Action Proponents propose to use more hours of hull-mounted surface ship sonar, and these activities are newly analyzed in the NOCAL range complex and in PMSR. Compared to the prior analysis, this analysis considers increased use of MF1 (regular duty cycle) and MF1C (continuous duty cycle) associated with Navy training activities and decreased use of MF1 and MF1C associated with Navy testing activities. This analysis also considers the training and testing usage of these sonars across an expanded study area.

For the maximum analyzed year of training and testing activities under this proposed action, MF1 has increased 20 percent and MF1C has increased 50 percent in the expanded California Study Area (which now includes PMSR and NOCAL)). In the Hawaii Study Area MF1 and MF1C is proposed to increase greater than 10 percent and 60 percent respectively when compared to the prior HSTT analysis.

The largest activities in terms of number of platforms using sonar and event duration are major training exercises. These are multi-day exercises that transition across large areas and involve multiple anti-submarine warfare assets. Although major training exercises tend to move to different locations as the event unfolds, some animals could be exposed to sonars over multiple days and across a large area. Integrated and coordinated training similarly involve multiple anti-submarine warfare platforms, but these activities are of shorter duration, smaller scale, and fewer participants than major training exercises. Unit-level training typically involves a single platform conducting anti-submarine warfare. Testing activities are often on the scale of unit-level training. These events would be conducted across a smaller area and for a shorter period, usually within a few hours of a single day, although certain vessel evaluation activities using anti-submarine warfare sonars may extend over multiple days.

Individual ships and submarines would use their anti-submarine warfare sonars during maintenance of these systems. These smaller scale events are less likely to repeatedly expose any marine mammals when these events are considered individually; however, these events may be concentrated in certain locations, such as Sonar Maintenance events at piers conducted near homeports, increasing the potential to repeatedly expose local populations. Except for nearshore maintenance activities and system checks, anti-submarine warfare sonars would typically be used in water deeper than approximately 200 meters (m). Thus, in most locations near-shore populations would not be impacted by these activities.

- Mine Warfare training and testing activities typically involve a ship, helicopter, or unmanned vehicle using a mine-hunting sonar to locate mines. Most Mine Warfare sonar systems have a lower source level, higher frequency, and narrower, often downward facing beam pattern as compared to most anti-submarine warfare sonars. Because of these factors, zones of effect for these systems tend to be relatively smaller. Mine Warfare activities may extend from hours to days. Despite relatively lower source levels, long duration events may still pose a risk of auditory effects due to accumulated exposure to any animal that remains in the vicinity. These activities would typically occur offshore throughout the Study Area but would also occur closer to shore at designated training and testing areas near San Diego, San Clemente Island, Silver Stand Training Complex, Pearl Harbor, and other designated locations around Oahu (see Appendix H, Description of Systems and Ranges, of the HCTT EIS/OEIS).
- Navigation and object detection activities typically employ ship and submarine-based sonars to navigate and avoid underwater objects. Submarines will use their low duty cycle sonars to navigate near ports or train for simulated under ice conditions farther offshore. Surface ships will use hull-mounted sonar at higher frequencies (e.g., bin MF1K) to detect and avoid hazards. The activities would typically occur in Hawaii and SOCAL Range Complexes and while navigating near homeports (San Diego and Pearl Harbor).
- Unmanned underwater vehicles (UUV) typically employ sonars with higher frequencies and lower source levels. These activities therefore typically have a smaller zone of effect. Still, because some

sonars on UUVs have high duty cycles and UUVs may be active for hours at a time, there is a risk of longer exposures for nearby animals. In addition, low-frequency and mid-frequency sonars may be used during some activities.

- A variety of sound sources are used in other testing activities. Acoustic and oceanographic research activities use a variety of sonars to conduct engineering tests of acoustic sources, validate ocean acoustic models, and characterize how sound travels and interacts with the ocean bottom, fish, and ocean surface. Other Testing activities include but are not limited to testing of communication sound sources and countermeasures. Most of these systems generate low to moderate sound levels. Some sources are stationary. Certain events may use sources over long durations (days) which may result in long duration exposures to animals that remain in the vicinity.

Sonars have the potential to affect marine mammals by causing hearing loss, masking, non-injurious physiological responses (such as stress), or behavioral reactions. Low- (less than 1 kHz), mid- (1–10 kHz), and some high (10–100 kHz) frequency sonars are within the hearing range of all marine mammals, though odontocetes hear poorly at low frequencies. Additionally, very high-frequency (100–200 kHz) sonars are in the hearing range of all odontocetes. See the section titled *Hearing* in the *Marine Mammal Background* for additional information.

Hearing Loss: Hearing loss, or threshold shift, is related to the received level of sound and the duration of the exposure. Proposed activities with more sound sources, louder sound sources, or that transmit sonar for longer durations increase the likelihood of auditory effects in marine mammals. For example, high-duty cycle hull-mounted sonar is more likely than other sonars to result in auditory effects. Research has shown that marine mammals are more susceptible to hearing loss within frequencies of best hearing. Hearing loss is most likely to occur at or above the dominant frequency of the sound source, not below. The recovery of hearing thresholds begins after an exposure. Any hearing loss that is recovered is called temporary threshold shift (TTS), whereas any remaining threshold shift after recovery is considered AINJ. See the section titled *Hearing Loss and Auditory Injury* in the *Marine Mammal Acoustic Background* for additional information. TTS and AINJ due to sonars are estimated using criteria developed for marine mammal hearing groups and modeling methods described below in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors).

Masking: Masking can reduce the ranges over which marine mammals can detect biologically relevant sounds in the presence of high-duty cycle sources. Lower-duty cycle sonars have less of a masking effect, as the listener can detect signals of interest during the quiet periods between cycles. The reduction in range over which marine mammals communicate is highly dependent on the frequencies of the sonar and biological signal of interest, as well as the source levels of the sonar. High-frequency (10–100 kHz) sonars, including those typically used for mine hunting, navigation, and object detection, fall within the best hearing and vocalization ranges of most marine mammals. These sources often have medium to high duty cycles, but typically have lower source levels than anti-submarine warfare sonars. High frequencies attenuate more rapidly in the water due to absorption than do lower frequency sounds, thus producing a smaller zone of potential masking than mid and low frequencies. While high-frequency sonar has the potential to mask marine mammal vocalizations under certain conditions, reduction in available communication space or ability to locate prey is unlikely because of the small zone of effect.

Masking effects of sonar are typically transient and temporary for most hull-mounted sonars, as they are mobile, and masking is reduced as the spatial separation between the masker and signal of interest increases. Most anti-submarine warfare activities are geographically dispersed and last for a few hours, often with intermittent sonar use, and have a narrow frequency band (typically less than one-third octave). These factors reduce the likelihood of masking due to sonar used in anti-submarine warfare activities. In some cases, mammals can compensate for masking by changing their calls or moving away from the source. Some of these activities use mid-frequency hull-mounted high duty cycle sonars (MF1C) that increase the potential for auditory effects and masking. Overall, the use of MF1C is low relative to the use of low duty cycle hull-mounted sonar (MF1).

For large mysticetes, the range of best hearing is estimated between 0.1 and 10 kHz, which overlaps with low- and mid-frequency sonar sources; however, their vocalizations are below 1 kHz, which overlaps with low-frequency sources. Any auditory impacts (TTS and INJ) or masking from mid-frequency sonars would be less likely to affect communication than impacts due to low-frequency sonars. For the other mysticetes, the range of best hearing and vocalizations is between 1 and 30 kHz, which overlaps with mid- and high-frequency sonar sources. Masking from high-frequency sonar sources would be less likely to affect communication for these mysticetes than impacts due to mid-frequency sonars.

Odontocetes that use echolocation to hunt may experience masking of the echoes needed to find their prey when foraging near low-frequency and mid-frequency sonar sources. Communication sounds could also be masked by these sources. This effect is likely to be temporary in offshore areas where these sources operate most often. However, when sonars operate in nearshore areas such as homeports with a high level of anthropogenic activity, the opportunities for odontocetes to detect and interpret biologically relevant sounds may be reduced. Odontocetes with very high frequency hearing such as harbor porpoises may experience masking of echolocation and communication calls from close-proximity very-high-frequency sources, but these effects are likely to be transient and temporary.

Pinnipeds may also experience masking due to low and mid- frequency sources because their communication calls range from approximately 0.1–30 kHz. Some species of pinnipeds communicate primarily in air and would not experience masking due to sonar.

See the section titled *Masking* in the *Marine Mammal Acoustic Background* for additional information.

Physiological response (stress): Physiological stress is an adaptive process that helps an animal cope with changing conditions. Marine mammals could experience a physiological change in heart rate, stress hormones, or immune system due to sound exposure. Currently, the sound characteristics that correlate with physiological responses in marine mammals are poorly understood, as are the ultimate consequences of these changes. Because there are many unknowns regarding the occurrence of acoustically induced stress responses in marine mammals, any physiological response (e.g., hearing loss or injury) or significant behavioral response is assumed to be associated with a stress response. See the section titled *Physiological Response* in the *Marine Mammal Acoustic Background* for additional information.

Behavioral response: Marine mammals only behaviorally respond to sounds they can hear or otherwise perceive. Marine mammals may react in several ways depending on the sound's characteristics, their experience with the sound source, and whether they are traveling, breeding, or feeding. Behavioral responses may include alerting, terminating feeding dives and surfacing, diving, or swimming away. Marine mammals' reaction to sonar can vary based on the individual, species, and context. See the section titled *Behavioral Reactions* in the *Marine Mammal Acoustic Background* for additional information, including a summary of best available science and supporting citations for responses to sonars by each of the behavioral groups listed below. Behavioral responses to sonars are estimated using criteria developed for marine mammal behavioral groups and modeling methods described below in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). The sensitivity to behavioral disturbance due to sonars differs among marine mammal groups as follows:

- Mysticetes are the least behaviorally sensitive group. Behavioral reactions in mysticetes are much more likely within a few kilometers of a sound source. Mysticetes have been observed to route around sound sources placed in their migration path.
- Large odontocetes such as killer whales and pilot whales have been observed to temporarily cease natural behaviors such as feeding, avoid the sonar source, or even move towards the sound source, as seen in pilot whales. These same behavioral responses have been observed in delphinids, both in captivity and in the field; however, this group appears to be less sensitive to sound and anthropogenic disturbance than other cetacean species.
- Responses of beaked whales have been carefully studied on Navy ranges, including the Southern California Anti-Submarine Warfare Range (SOAR) west of San Clemente Island in the SOCAL Range Complex and the Pacific Missile Range Facility (PMRF) west of Kauai, Hawaii. Beaked whales exposed to sonar or other active acoustic sources may discontinue feeding dives and avoid the area during anti-submarine warfare activities. In areas where anti-submarine warfare training exercises occur with some regularity, beaked whales leave the area but return within a few days after the event ends (e.g., Henderson et al., 2015; Henderson et al., 2016; Jacobson et al., 2022; Manzano-Roth et al., 2016; Tyack et al., 2011). Population levels of beaked whales and other odontocetes on Navy fixed ranges that have been operating for decades appear to be stable. In areas where beaked whales are unlikely to regularly encounter naval sonar activity, beaked whales may be more likely to be displaced for longer periods of time (e.g., Stanistreet et al., 2022). Significant behavioral reactions to sonar are likely when beaked whales are exposed to anti-submarine sonar within a few tens of kilometers, especially for prolonged periods (a few hours or more). Avoidance likely decreases the potential for hearing loss for these species.
- Harbor porpoises are small odontocetes that are sensitive to anthropogenic activity and avoid anthropogenic sound sources at low received levels. Behavioral reactions are more likely than with most other odontocetes.
- Pinnipeds in water are generally tolerant of anthropogenic sound and activity. They may not react at all until the sound source is approaching within a few hundred meters and then may alert, ignore the stimulus, change their behaviors, or avoid the immediate area by swimming away, diving, or hauling out.

For sonars with applicable activity-based mitigation (see *Mitigation*), trained Lookouts observe defined mitigation zones for marine mammals and indicators that marine mammals may be present. The mitigation zones encompass the ranges to auditory injury for all marine mammals for all sonars shown in 2.5.1 (Ranges to Effects for Sonars and Other Transducers), including the ship hull-mounted sonars, MF1 and MF1C.

Because sonars may result in the incidental take of marine mammals (auditory impacts and significant behavioral responses), sonar impacts are modeled per the methods presented in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Impacts on each marine mammal stock are discussed and quantified below in Section 2.4 (Species Impact Assessments). Conclusions *regarding impacts from sonars used during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).*

2.1.2 Impacts from Air Guns

Air guns use bursts of pressurized air to create intermittent, broadband, impulsive sounds. Air gun use during military readiness activities is limited and unlike large-scale seismic surveys that use multiple large air guns. Air gun use would occur nearshore in the SOCAL Range Complex under Intelligence, Surveillance, and Reconnaissance activities, and greater than 3 NM from shore in the Hawaii, NOCAL, and SOCAL Range Complexes under Acoustic and Oceanographic Research.

Air gun sounds are within the hearing range of all marine mammals. Potential impacts from air guns could include temporary hearing loss, masking, behavioral reactions, and physiological responses (stress).

All marine mammals are susceptible to auditory effects from impulsive sounds such as those from air guns. TTS and AINJ due to air guns are estimated using criteria developed for marine mammal hearing groups and modeling methods described below in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Ranges to auditory effects for marine mammals exposed to air guns are in Section 2.5.2 (Ranges to Effects for Air Guns). When using air guns, trained Lookouts observe defined mitigation zones for marine mammals and indicators that marine mammals may be present (see *Mitigation*). The mitigation zones encompass the ranges to auditory injury for all marine mammals.

If marine mammals are exposed to sounds from air guns, they may experience masking and could potentially react with short-term behavioral reactions and physiological response (see the *Marine Mammal Acoustic Background* section for details). It should be noted that many observations of marine mammal reactions to air guns are from oil and gas exploration activities that use large air gun arrays and operate continuously for multiple weeks to cover large areas of the ocean. Military readiness activities, in contrast, use fewer air guns over a much shorter period and a limited area. Reactions are less likely to occur or rise to the same level of severity as during seismic surveys.

Impacts from seismic air guns have been studied in several mysticete species, including gray whales, humpback whales, and blue whales. Mysticetes react to air guns in a variety of ways, ranging from startle responses, changing respiration, vocal, dive, or surface behaviors (e.g., tail slapping), and strong avoidance responses (e.g., swimming rapidly away from the seismic vessels, habitat displacement). Exposed mysticetes will sometimes tolerate the disturbance and continue their natural behavior patterns or return to the area once the air gun activity ceases. Certain factors (e.g., activity intensity, proximity, behavioral context, species) may influence whether a mysticete tolerates air gun noise or leaves the area until the seismic activity ceases.

Impacts from air guns have been studied in several odontocete species, including sperm whales, beluga whales, and harbor porpoises. Odontocetes may react in a variety of ways to air guns, which include changes in feeding, dive, and vocal behavior, habitat displacement, or showing no response at all. If disturbed while engaged in activities such as feeding or reproductive behaviors, odontocetes may be more likely to ignore or tolerate the disturbance and continue their natural behavior patterns, as seen in sperm whales.

Impacts from air guns have not been studied in many species of pinnipeds, but there is evidence of wild ringed seals avoiding a seismic vessel by a short distance (less than 250 m). Research in captive pinnipeds shows mild evasive behavioral responses. Pinnipeds may be the least sensitive taxonomic group to most noise sources and are likely to respond to loud impulsive sound sources only at close ranges by startling or ceasing foraging, but only for brief periods before returning to their previous behavior. Pinnipeds may even experience mild TTS before exhibiting a behavioral response (Southall et al., 2007). If disturbed while engaged in activities such as feeding or reproductive behaviors, pinnipeds may be more likely to ignore or tolerate the disturbance and continue their natural behavior patterns.

Because noise from air guns may result in the incidental take of marine mammals (auditory impacts and significant behavioral responses), air gun impacts are modeled per the methods presented in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). *Impacts on each marine mammal stock are quantified below in Section 2.4 (Species Impact Assessments). Conclusions regarding impacts from air guns used during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).*

2.1.3 Impacts from Pile Driving

Marine mammals could be exposed to sounds from impact (installation only) and vibratory (installation and extraction) pile driving during the Expeditionary Warfare activity - Port Damage Repair training at Port Hueneme, California throughout the year (pile driving would not occur during testing activities). No other locations within the HCTT Study Area would have pile driving activity. Only two species are anticipated to be present where pile driving activities would take place: California sea lions and harbor seals. There are no critical habitats that would be impacted by pile driving activities. There would be no impacts due to pile driving for any stock of marine mammal in California outside of Port Hueneme, because there is no geographic overlap of pile driving with species occurrence. Although some coastal species passing near the entrance of the port may detect sound from pile driving activities, behavioral responses from these exposures are not expected to rise to the level of take under military readiness.

Port Damage Repair training activities are made up of multiple events, each which could occur up to 12 times per year. Each training event is comprised of up to seven separate modules, each which could occur up to three iterations during a single event (for a maximum of 21 modules). Training events would last a total of 30 days, of which pile driving is only anticipated to occur for a maximum of 14 days. Sound from pile driving activities could occur over several hours in each day, though breaks in pile driving are taken frequently to reposition the drivers between piles. Depending on where the activity occurs at Port Hueneme, transmission of pile driving noise may be reduced by existing pier structures. As a standard operating procedure, the Navy performs soft starts at reduced energy during an initial set of strikes from an impact hammer. Soft starts may “warn” marine mammals and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Soft starts were not considered when calculating the number of marine mammals that could be impacted, nor was the possibility that marine mammals could avoid the training area. Therefore, absent these considerations, the impact determination is overly conservative.

Sounds from the impact hammer are impulsive, broadband, and dominated by lower frequencies. The impulses are within the hearing range of marine mammals. Sounds produced from a vibratory hammer are similar in frequency range as that of the impact hammer, except the levels are much lower than for the impact hammer, especially when extracting piles from sandy, nearshore ground, and the sound is continuous while operating. AINJ, TTS, and behavioral responses due to pile driving are estimated using criteria developed for marine mammal hearing groups and modeling methods described below in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Ranges to effects for marine mammals exposed to impact and vibratory pile driving are shown in Section 2.5.3

(Ranges to Effects for Pile Driving). During pile driving, trained Lookouts observe defined mitigation zones for marine mammals and indicators that marine mammals may be present (see *Mitigation*). The pile driving mitigation zone (100 yd.) encompasses the ranges to AINJ for otariids and, for most pile types, phocids, as well as the ranges to TTS for a subset of pile types for otariids and phocids. After a sighting, the 15-min. recommencement wait period would cover the average dive times of the marine mammal species that could be present in the mitigation zone, especially considering the shallow waters inside the port where pile driving activities occur. If impacts occur, it would be more likely that marine mammals may experience brief periods of masking, physiological responses, or behavioral reactions.

Vibratory and impact pile driving (at 60 strikes per minute) may cause masking. The effect would be temporary, lasting the amount of time it would take to drive a pile, with pauses before the next pile is driven. Furthermore, Port Damage Repair activities occur in shallow, nearshore areas where ambient noise levels are already typically high. Port Hueneme is a military port with potentially high ambient noise levels due to vessel traffic and port activities. Given these factors, significant masking is unlikely to occur in marine mammals due to exposure to sound from impact pile driving or vibratory pile driving/extraction.

If marine mammals are exposed to sounds from pile driving or extraction, they could potentially react with physiological (stress) responses, short-term behavioral reactions, or be displaced from the port (see the *Marine Mammal Acoustic Background* section).

Because noise from pile driving may result in the incidental take of marine mammals (auditory impacts and significant behavioral responses), pile driving impacts are modeled per the methods presented in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Impacts on each marine mammal stock present in the affected area are quantified below in Section 2.4 (Species Impact Assessments). Conclusions regarding impacts from pile driving during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).

2.1.4 Impacts from Vessel Noise

Marine mammals may be exposed to vessel-generated noise throughout the Study Area. Military readiness activities with vessel-generated noise would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Specifically, Navy vessel traffic in Hawaii is heaviest south of Pearl Harbor, and in Southern California Navy vessel traffic is heaviest around San Diego and roughly within 50 NM of shore, though these activities could occur throughout the Study Area, as described in the *Acoustic Habitat* section. The four amphibious approach lanes on the coast of central California bordering NOCAL and PSMR near Mill Creek Beach, Morro Bay, Pismo Beach, and Vandenberg Space Force Base are sources of nearshore vessel noise as well. Navy traffic has clear routes from Hawaii to the Mariana Islands, Japan and San Diego, and from San Diego north to the Pacific Northwest. Vessel movements involve transits to and from ports to various locations within the Study Area. Many ongoing and proposed military readiness activities involve maneuvers by various types of surface ships, boats, and submarines (collectively referred to as vessels), as well as unmanned systems. During training, combatant speeds generally range from 10 to 14 knots; however, vessels can and will, on occasion, operate within the entire spectrum of their specific operational capabilities. A variety of smaller craft and unmanned vessels can be operated within the Study Area. Small craft types, sizes, and speeds vary. In all cases, the vessels will be operated in a safe manner consistent with the local conditions. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours up to multiple weeks.

Noise from vessels generally lacks the amplitude and duration to cause any hearing loss in marine mammals under realistic conditions. Noise from vessels is generally low-frequency (10 to hundreds of Hertz), although at close range or in shallow water some sound energy can extend above 100 kHz at received levels above 100 dB re 1 µPa (Hermannsen et al., 2014). Although periods of broadband noise tend to be brief, occurring only as a vessel is passing within a few hundred meters, vessel noise could lead to short-term masking for all marine mammal species. Vessels have been linked to minor behavioral responses, although it is difficult to separate responses to the noise from reactions to the physical presence of the vessel. Physiological response has also been linked to chronic vessel noise, such as that in shipping lanes or heavily trafficked whale-watch areas. However, based on the relatively low source levels of many vessels, and the transient nature of vessel noise during military readiness activities, any responses by marine mammals to vessels and associated noise are unlikely to be significant. Best available science on responses to vessel noise, including behavioral responses, stress, and masking, is summarized in the *Marine Mammal Acoustic Background* section.

Vessel traffic related to the proposed activity would pass near marine mammals on an incidental basis. Ports such as Honolulu and San Diego are heavily trafficked with private and commercial vessels in addition to naval vessels. Non-military vessels dominate vessel traffic in shipping lanes off California, including out of the major ports of San Francisco, Los Angeles, and Long Beach (see maps of total and military vessel traffic off Hawaii and California in *Acoustic Habitat*). Proposed military vessel transits would comprise a small portion of overall vessel traffic and are unlikely to cause significant behavioral responses or long-term abandonment of habitat by a marine mammal. The Action Proponents will implement mitigation for vessel movement to avoid the potential for marine mammal vessel strikes, as discussed in the *Mitigation* section. The mitigation for vessel movements (i.e., maneuvering to maintain a specified distance from a marine mammal) will also help the Navy avoid or reduce potential impacts from vessel noise on marine mammals.

When the level of vessel noise is above the sound of interest, and in a similar frequency band, masking could occur (see the section titled *Masking* in the *Marine Mammal Acoustic Background*). Vessel noise can mask vocalizations and other biologically relevant sounds (e.g., sounds of prey or predators) that marine mammals rely on. Potential masking can vary depending on the ambient noise level within the environment, the received level and frequency of the vessel noise, and the received level, frequency, and relative position of the sound of biological interest. In the open ocean, ambient noise levels are between about 60 and 80 dB re 1 µPa in the band between 10 Hz and 10 kHz due to a combination of natural (e.g., wind) and anthropogenic sources (Urick, 1983), while inshore noise levels, especially around busy ports, can exceed 120 dB re 1 µPa. This analysis assumes that any sound that is above ambient noise levels and within an animal's hearing range may potentially cause masking. However, the degree of masking increases with increasing noise levels; a noise that is just detectable over ambient levels is unlikely to cause any substantial masking. Masking by passing ships or other sound sources transiting the Study Area would be short term and intermittent, and therefore unlikely to result in any substantial costs or consequences to individual animals or populations. Areas with increased levels of ambient noise from anthropogenic noise sources such as areas around busy shipping lanes and near harbors and ports may cause sustained levels of masking for marine mammals, which could reduce an animal's ability to find prey, find mates, socialize, avoid predators, or navigate. However, Navy vessels make up a very small percentage of the overall traffic (two orders of magnitude lower than commercial ship traffic in the Study Area), and the rise of ambient noise levels in these areas is related to all ocean users, including commercial and recreational vessels and shoreline development and industrialization.

Surface combatant ships (e.g., guided missile destroyer, guided missile cruiser, and Littoral Combat Ship) and submarines are designed to be very quiet to evade enemy detection and typically travel at speeds of 8 - 15 knots. Actual acoustic signatures and source levels of combatant ships and submarines are classified; however, they are quieter than most other motorized ships. Still, these surface combatants and submarines are likely to be detectable by marine mammals over open-ocean ambient noise levels at distances of up to a few kilometers, which could cause masking for a few minutes as the vessel passes by. Other Navy ships and small vessels have higher source levels, like equivalently sized commercial ships and private vessels, however many of these are concentrated in homeports, which are typically industrialized areas with elevated ambient noise levels.

Ship noise tends to be low-frequency and broadband; therefore, it may have the largest potential to mask mysticetes that vocalize at lower frequencies compared to other marine mammals. Noise from large vessels and outboard motors on small craft can produce source levels of 160 to over 200 dB re 1 μPa at 1 m. Therefore, in the open ocean, noise from noncombatant vessels may be detectable over ambient levels for tens of kilometers, and some masking, especially for mysticetes, is possible. In noisier inshore areas around ports and ranges, vessel noise may be detectable above ambient for only several hundred meters. Some masking of mysticete communication is likely from noncombatant vessels, on par with similar commercial and recreational vessels, especially in quieter, open-ocean environments.

Vessel noise has the potential to disturb marine mammals and elicit an alerting, avoidance, or other behavioral reaction. Most studies have reported that marine mammals react to vessel sounds and traffic with short-term interruption of feeding, resting, or social interactions (Magalhães et al., 2002; Richardson et al., 1995; Watkins, 1981). Some species respond negatively by retreating or responding to the vessel antagonistically, while other animals seem to ignore vessel noises altogether or are attracted to the vessel (Watkins, 1986). Marine mammals are frequently exposed to vessels due to research, ecotourism, commercial and private vessel traffic, and government activities. It is difficult to differentiate between responses to vessel sound and visual cues associated with the presence of a vessel; thus, it is assumed that both play a role in prompting reactions from animals.

Based on studies of several species, mysticetes are not expected to be disturbed by vessels that maintain a reasonable distance from them, which varies with vessel size, geographic location, and tolerance levels of individuals. Pinniped data largely indicates tolerance of vessel approaches, especially for animals in the water. Odontocetes could have a variety of reactions to passing vessels, including attraction, bow-riding, increased traveling time, decreased feeding behaviors, diving, or avoidance of the vessel, which may vary depending on their prior experience with vessels. Kogia whales, harbor porpoises, and beaked whales have been observed avoiding vessels. Some masking to odontocete communication is likely from noncombatant vessels, on par with similar commercial and recreational vessels, especially in quieter, open-ocean environments.

Vessels operated by the Action Proponents do not purposefully approach marine mammals and are not expected to elicit significant behavioral responses. Marine mammal reactions to vessel noise associated with proposed activities are likely to be minor and short term, leading to no significant reactions and no long-term consequences.

Pursuant to the MMPA, vessel noise during military readiness activities as described under the Proposed Action will not result in the unintentional taking of marine mammals incidental to those activities. Conclusions regarding impacts from activities that produce vessel noise during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).

2.1.5 Impacts from Aircraft Noise

Marine mammals may be exposed to aircraft-generated noise throughout the Study Area. Military readiness activities with aircraft would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Both manned and unmanned fixed- and rotary-wing (e.g., helicopters) aircraft are used for a variety of military readiness activities throughout the Study Area. Tilt-rotor impacts would be similar to fixed-wing or rotary-wing aircraft impacts, depending on the aircraft mode. Most of these sounds would be concentrated around airbases and fixed ranges within each of the range complexes. Aircraft noise could also occur in the waters immediately surrounding aircraft carriers at sea during takeoff and landing or directly below hovering rotary-wing aircraft that are near the water surface.

Aircraft produce extensive airborne noise from either turbofan or turbojet engines. An infrequent type of aircraft noise is the sonic boom, produced when the aircraft exceeds the speed of sound. Rotary-wing aircraft produce low-frequency sound and vibration. Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors, but significant acoustic energy is primarily transmitted into the water directly below the craft in a narrow cone, as discussed in detail in the *Acoustic Primer* section. Underwater sounds from aircraft are strongest just below the surface and directly under the aircraft. Additional characteristics of aircraft noise are described in the *Acoustic Stressors* section.

Sound from aircraft noise, including occasional sonic booms, lack the amplitude or duration to cause any hearing loss in marine mammals underwater. Aircraft would pass quickly overhead and rotary-wing aircraft (e.g., helicopters) may hover at lower altitudes for longer durations, though still for relatively brief periods, considering the transient nature of both the aircraft and marine mammals. Potential impacts from aircraft noise are limited to masking of other biologically relevant sounds, and brief behavioral and physiological response reactions as aircraft passes overhead. Based on the short duration of potential exposure to aircraft noise, behavioral and physiological response reactions, if they did occur, are unlikely to be significant. The duration of masking due to hovering rotary-wing aircraft would be limited to the short duration of hovering events.

Marine mammals may respond to both the physical presence and to the noise generated by aircraft, making it difficult to attribute causation to one or the other stimulus. In addition to noise produced, all low-flying aircraft make shadows, which can cause animals at the surface to react. Rotary-wing aircrafts may also produce strong downdrafts, a vertical flow of air that becomes a surface wind, which can also affect an animal’s behavior at or near the surface.

Many of the observations of marine mammal reactions are to aircraft flown for whale-watching and marine research purposes. Marine mammal survey aircraft are typically used to locate, photograph, track, and sometimes follow animals for long distances or for long periods of time, all of which results in the animal being much more frequently located directly beneath the aircraft (in the cone of the loudest noise and potentially in the shadow of the aircraft) for extended periods. Military aircraft would not follow marine mammals. In contrast to whale-watching excursions or research efforts, overflights would not result in prolonged exposure of marine mammals to overhead noise or encroachment.

In most cases, exposure of a marine mammal to fixed-wing aircraft presence and noise would be brief as the aircraft quickly passes overhead. Animals would have to be at or near the surface at the time of an overflight to be exposed to appreciable sound levels. Takeoffs and landings occur at established airfields as well as on vessels at sea at unspecified locations across the Study Area. Takeoffs and landings from vessels could startle marine mammals; however, these events only produce in-water noise at any given location for a brief period as the aircraft climbs to cruising altitude. Some sonic booms from aircraft could startle marine mammals, but these events are transient and happen infrequently at any given location within the Study Area. Repeated exposure to most individuals over short periods (days) is extremely unlikely, except for animals that are resident in inshore locations around ports, on fixed ranges (e.g., SOAR), or during major training exercises. These animals could be subjected to multiple overflights per day; however, aircraft would pass quickly overhead, typically at altitudes above 3,000 ft., which would make marine mammals unlikely to respond. No long-term consequences for individuals or populations would be expected.

Daytime and nighttime activities involving rotary-wing aircrafts may occur for extended periods of time, typically 1 to 3 hours in some areas. During these activities, rotary-wing aircrafts would typically transit throughout an area and may hover over the water. Longer activity durations and periods of time where rotary-wing aircrafts hover may increase the potential for behavioral reactions, startle reactions, and physiological response. Low-altitude flights of rotary-wing aircrafts during some activities, often under 100 ft., may elicit a somewhat stronger behavioral response due to the proximity to marine mammals, the slower airspeed and therefore longer exposure duration, and the downdraft created by the rotary-wing aircraft's rotor. Marine mammals would likely avoid the area under the rotary-wing aircraft.

Most fixed-wing aircraft and rotary-wing aircraft activities are transient in nature, although rotary-wing aircrafts could also hover for extended periods (5 to 15 minutes). The likelihood that marine mammals would occur or remain at the surface while an aircraft transits directly overhead would be low. Rotary-wing aircrafts that hover in a fixed location for an extended period could increase the potential for exposure. However, impacts from military readiness activities would be highly localized and concentrated in space and duration.

The consensus of all the studies reviewed is that aircraft noise would cause only small temporary changes in the behavior of marine mammals. Specifically, marine mammals at or near the surface when an aircraft flies overhead at low altitude may startle, divert their attention to the aircraft, or avoid the immediate area by swimming away or diving. No more than short-term reactions are likely. No long-term consequences for individuals, species, or stocks would be expected.

Pursuant to the MMPA, aircraft noise during military readiness activities as described under the Proposed Action will not result in the unintentional taking of marine mammals incidental to those activities. Conclusions regarding impacts from activities that produce aircraft noise during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).

2.1.6 Impacts from Weapons Noise

Marine mammals may be exposed to sounds caused by the firing of weapons, objects in flight, and impact of non-explosive munitions on the water surface during activities conducted at sea.[1] This incidental noise is collectively called weapons noise. Military readiness activities using gunnery and other weapons that generate firing noise would be conducted as described in the *Proposed Activities*

[1] Impacts on hauled-out pinnipeds due to land-based launches at San Nicolas Island in PMSR and at the PMRF in the Hawaii Range Complex are addressed separately.

and *Activity Descriptions* sections*.* The locations where gunnery and other munitions may be used are shown in the *Munitions* data section. Most weapons noise is attributable to gunnery activities.

Most activities involving large caliber naval gunfire or other munitions fired or launched from a vessel are conducted more than 12 NM from shore. The Action Proponents will implement mitigation to avoid or reduce potential impacts from weapon firing noise during large-caliber gunnery activities, as discussed in the *Mitigation* section. For explosive munitions, only associated firing noise is considered in the analysis of weapons noise. The noise produced by the underwater detonation of explosive weapons is analyzed in Section 2.1.7 (Impacts from Explosives).

The firing of a weapon may have several components of associated noise. Firing of guns could include sound generated in air by firing a gun (muzzle blast) and a crack sound due to a low amplitude shock wave generated by a supersonic projectile. Most in-air sound would be reflected at the air-water interface. Underwater sounds would be strongest just below the surface and directly under the firing point. Any sound that enters the water only does so within a narrow cone below the firing point or path of the projectile. Vibration from the blast propagating through a ship's hull, the sound generated by the impact of an object with the water surface, and the sound generated by launching an object underwater are other sources of impulsive sound in the water. Sound due to missile and target launches is typically at a maximum at initiation of the booster rocket.

A gun fired from a ship on the surface of the water propagates a blast wave away from the gun muzzle into the water. Average peak sound pressure in the water measured directly below the muzzle of the gun and under the flight path of the shell (assuming it maintains an altitude of only a few meters above the water surface) was approximately 200 dB re 1 µPa. Animals at the surface of the water, in a narrow footprint under a weapons trajectory, could be exposed to naval gunfire noise and may exhibit brief startle reactions, avoidance, diving, or no reaction at all. Due to the short term, transient nature of gunfire noise, animals are unlikely to be exposed multiple times within a short period. Behavioral reactions would likely be short term (minutes) and are unlikely to lead to substantial costs or long-term consequences for individuals, species, or stocks.

Sound due to Missile and Target Launches is typically at a maximum at initiation of the booster rocket and rapidly fades as the missile or target travels downrange. These sounds would be transient and of short duration, lasting no more than a few seconds at any given location. Many missiles and targets are launched from aircraft, which would produce minimal noise in the water due to the altitude of the aircraft at launch. Missiles and targets launched by ships or near the water surface may expose marine mammals to levels of sound that could produce brief startle reactions, avoidance, or diving. Due to the short-term, transient nature of launch noise, animals are unlikely to be exposed multiple times within a short period. Reactions by marine mammals to these specific stressors have not been recorded; however, marine mammals would be expected to react to weapons noise as they would other transient sounds. Behavioral reactions would likely be short term (minutes) and are unlikely to lead to long-term consequences for individual, species, or stocks.

Some objects, such as certain non-explosive practice munitions, could impact the water with great force. Animals within the area may hear the impact of non-explosive ordnance on the surface of the water and would likely alert, startle, dive, or avoid the immediate area. Significant behavioral reactions from marine mammals would not be expected due to non-explosive ordnance impact noise; therefore, long-term consequences for the individual, species, or stocks are unlikely.

Pursuant to the MMPA, weapons noise during military readiness activities as described under the Proposed Action will not result in the unintentional taking of marine mammals incidental to those activities. Conclusions regarding impacts from activities that produce weapons noise during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).

2.1.7 Impacts from Explosives

Marine mammals may be exposed to sound and energy from explosions in the water and near the water surface associated with the proposed activities. Activities using explosives would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Most explosive activities would occur in the SOCAL Range Complex, the Hawaii Range Complex, and PMSR, although activities with explosives would also occur in other areas as described in the *Activity Descriptions* section.

Characteristics, quantities, and net explosive weights of in-water explosives used during military readiness activities are provided in the *Acoustic Stressors* section. The use of in-water explosives would increase from the prior analysis for training activities and would decrease slightly for testing. There is an overall reduction in the use of most of the largest explosive bins (bin E8 [> 60–100 pounds (lb.) net explosive weight (NEW)] and above) for training and a decrease in two of the largest explosive bins (bin E10 [> 250–500 lb. NEW] and E11 [> 500–650 lb. NEW]) under testing activities. There would be notable increases in the smaller explosive bins (E7 [> 20–60 lb. NEW] and below) under training and testing activities, except for bin E1 (0.1–0.25 lb. NEW) which would decrease under testing activities. Small ship shock trials (bin E16 [> 7,250–14,500 lb. NEW]) not previously analyzed are currently proposed under testing activities.

Most activities involving in-water (including surface) explosives associated with large caliber naval

gunfire, missiles, bombs, or other munitions are conducted more than 12 NM from shore. This includes Small Ship Shock Trials that could occur in the SOCAL Range Complex. Sinking Exercises are conducted greater than 50 NM from shore.

Species present in shallower water could be exposed to activities conducted closer to shore. Certain activities with explosives may be conducted close to shore at locations identified in the Activity Descriptions section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS. This includes certain Mine Warfare and Expeditionary Warfare activities. In the Hawaii Range Complex explosive activities could occur at specified ranges and designated locations around Oahu, including the Puuloa Underwater Range and designated locations in and near Pearl Harbor. In the SOCAL Range Complex, explosive activities could occur near San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast.

The types of activities with detonations below the surface include Mine Warfare, activities using explosive torpedoes, and ship shock trials, as well as specific training and testing activities. Most explosive munitions used during military readiness activities, however, would occur at or just above the water surface (greater than 90 percent by count). These include those used during surface warfare activities, such as explosive gunnery, bombs, and missiles. Certain nearshore activities use explosives in the surf zone up to the beach, where most explosive energy is released in the air (refer to Appendix H, Description of Systems and Ranges, for location details). In the below quantitative analysis, impacts on marine mammals are over-estimated because in-air near surface and surf zone explosions are modeled as underwater explosions, with all energy assumed to remain in the water. Sound and energy from in-air detonations at higher altitudes would be reflected at the water surface and therefore are not analyzed further in this section and would have no effect on marine mammals.

Explosions produce loud, impulsive, broadband sounds that are within the hearing range of all marine mammals. Potential impacts from explosive energy and sound include mortality, non-auditory injury, behavioral reactions, physiological response, masking, and hearing loss.

Direct injury: The rapid, high magnitude pressure changes created by explosives can kill or injure marine mammals. Susceptibility to injury is estimated using data on terrestrial animals exposed to explosives. See the section titled *Direct Injury* in the *Marine Mammal Acoustic Background* for additional information.

Hearing loss: Exposure to an explosion may cause AINJ or TTS due to high intensity, broadband sounds with high peak pressures. There is limited information on hearing loss due to explosives, although there are data from other impulsive sources. See the sections titled *Hearing Loss and Auditory Injury* in the *Marine Mammal Acoustic Background* for additional information.

Masking: Activities that have multiple detonations such as some naval gunfire exercises may create brief periods of broadband masking of biologically relevant sounds. Because these periods are so brief, any impacts would be limited. See the sections titled *Masking* in the *Marine Mammal Acoustic Background* for additional information.

Behavioral and physiological (stress) response: If marine mammals are exposed to impulsive sounds such as those from explosives, they may react in a variety of ways, which may include alerting, startling, breaking off feeding dives and surfacing, diving, or swimming away, changing vocalization, or showing no response at all. Because noise from most activities using explosives is short term and intermittent, and because detonations usually occur within a small area, behavioral reactions from marine mammals are likely to be short-term and low to moderate severity. Physiological responses including stress responses could occur. See the sections titled *Physiological Response* and *Behavioral Reactions* in the *Marine Mammal Acoustic Background* for additional information.

Injury (including mortality), AINJ, TTS, and behavioral responses due to explosives are estimated using criteria developed for marine mammal hearing groups and modeling methods described below in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Impact ranges for marine mammals exposed to explosive sound and energy are shown in Section 2.5.4 (Ranges to Effects for Explosives).

As discussed in the *Mitigation* section, the Action Proponents will implement mitigation to relocate, delay, or cease detonations when a marine mammal is sighted within or entering a mitigation zone to avoid or reduce potential explosive impacts. The visual observation distances described in the section *Mitigation* are designed to cover the distance to mortality and reduce the potential for injury due to explosives. The quantitative analysis for this proposed action predicts that mortalities could occur. These predicted mortalities are shown in the quantified impacts on each stock in Section 2.4 (Species Impact Assessments) and are not further reduced to account for mitigation. Most training mortalities and a portion of the testing mortalities are attributable to Mine Warfare activities, including Mine Neutralization Explosive Ordnance Disposal, Amphibious Breaching, and Underwater Demolition Qualification and Certification. A large portion of the testing mortalities are attributable to Small Ship Shock Trial. Both types of activities have extensive pre- and during event visual observation requirements as described in *Mitigation* that would reduce the risk that these mortalities would occur. No marine mammal mortalities have been identified during multi-day post-event observations following previous Ship Shock Trials. One occurrence of mortalities due to placed explosives during a Navy activity is known (see *Direct Injury Due to Explosives* in the *Marine Mammal Background*).

Because in-water explosives may result in the incidental take of marine mammals (mortality, non-auditory injury, auditory effects, and significant behavioral responses), explosive impacts are modeled per the methods presented in Section 2.2 (Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors). Impacts on each marine mammal stock are quantified below in Section 2.4 (Species Impact Assessments). Conclusions regarding impacts from explosives used during military readiness activities for ESA-listed species are provided in Section 2.4 (Species Impact Assessments).

2.2 Quantifying Impacts on Marine Mammals from Acoustic and Explosive Stressors

The following section provides an overview of key components of the modeling methods used in this analysis to estimate the number and types of acoustic and explosive impacts on marine mammals. The *Quantitative Analysis TR, Criteria and Thresholds TR, Density TR,* and *Dive Profile TR* detail the quantitative process and show specific data inputs to the models. Except for pile driving, impacts are modeled using the Navy Acoustic Effects Model. Pile driving is modeled using methods described in the *Quantitative Analysis TR.* The detailed analysis of pile driving during Port Damage Repair training at Port Hueneme is in the *Pile Driving Analysis*.

2.2.1 The Navy Acoustic Effects Model

The Navy Acoustic Effects Model (NAEMO) was developed to conduct a comprehensive acoustic impact analysis for use of sonars, air guns, and explosives[2] in the marine environment. This model considers the physical environment, including bathymetry, seafloor composition/sediment type, wind speed, and sound speed profiles, to estimate propagation loss. The propagation information combined with data on the locations, numbers, and types of military readiness activities and marine resource densities provides estimated numbers of effects to each stock.

Individual animals are represented as "animats," which function as dosimeters and record acoustic energy from all active underwater sources during a simulation of a training or testing event. Each animat's depth changes during the simulation according to the typical depth pattern observed for each species. During any individual modeled event, impacts on individual animats are considered over 24-hour periods.

The model estimates the number of instances in which an effect threshold was exceeded over the course of a year, it does not estimate the number of times an individual in a population may be impacted over a year. Some individuals could be impacted multiple times, while others may not experience any impact.

NAEMO (described in the *Quantitative Analysis TR*) underwent several notable changes from the prior analysis that influence estimates of the number of marine mammals that could be impacted in each training or testing event.

- Broadband sonar bins are split into one octave sub-bins, propagation calculations performed, and then the energy in each one-octave bin is summed at the receiver (i.e., animat). Broadband sources

[2] Explosives analyzed in NAEMO include those that are expected to occur in air within 30 ft. (9 m) of the water surface (e.g., those that detonate at a surface target). These explosives are modeled at 0.1 m depth with no release at the surface.

were represented and modeled in previous analyses using only the source's center frequency. Using the full frequency spectrum of the source, as opposed to only the center frequency, may lead to higher weighted received levels for some hearing groups, dependent on the overlap of source frequencies with the auditory range of the hearing group. This will increase sound exposure level (SEL)-based impacts (i.e., TTS and AINJ) for broadband sources in this analysis versus prior analyses for the same event. Sometimes in prior analyses, broadband sonar sources were not analyzed for some hearing groups if the center frequency was beyond the group's frequency cutoffs. Now considering the full broadband frequency spectra of the signal, some previously discounted hearing groups are now assessed for impacts from those sources.

- The impulsive propagation model was updated to use an equation that was more suitable for use in water. The total peak pressure and overall energy of both equations is the same. However, because of the slower decay time of the updated equation, there would be a slight increase in modeled non-auditory injury and mortality as compared to prior analyses.
- Animal avoidance of high source levels was incorporated into the Navy Acoustic Effects Model, with marine mammal avoidance thresholds based on their sensitivity to behavioral response. Some species that are less sensitive to behavioral response (i.e., most odontocetes and mysticetes) had less reduction in AINJ due to avoidance than in the prior analysis, leading to higher AINJ estimates. Additional details on the avoidance process are discussed further in Section 2.2.2 (Quantifying Impacts on Hearing).

2.2.2 Quantifying Impacts on Hearing

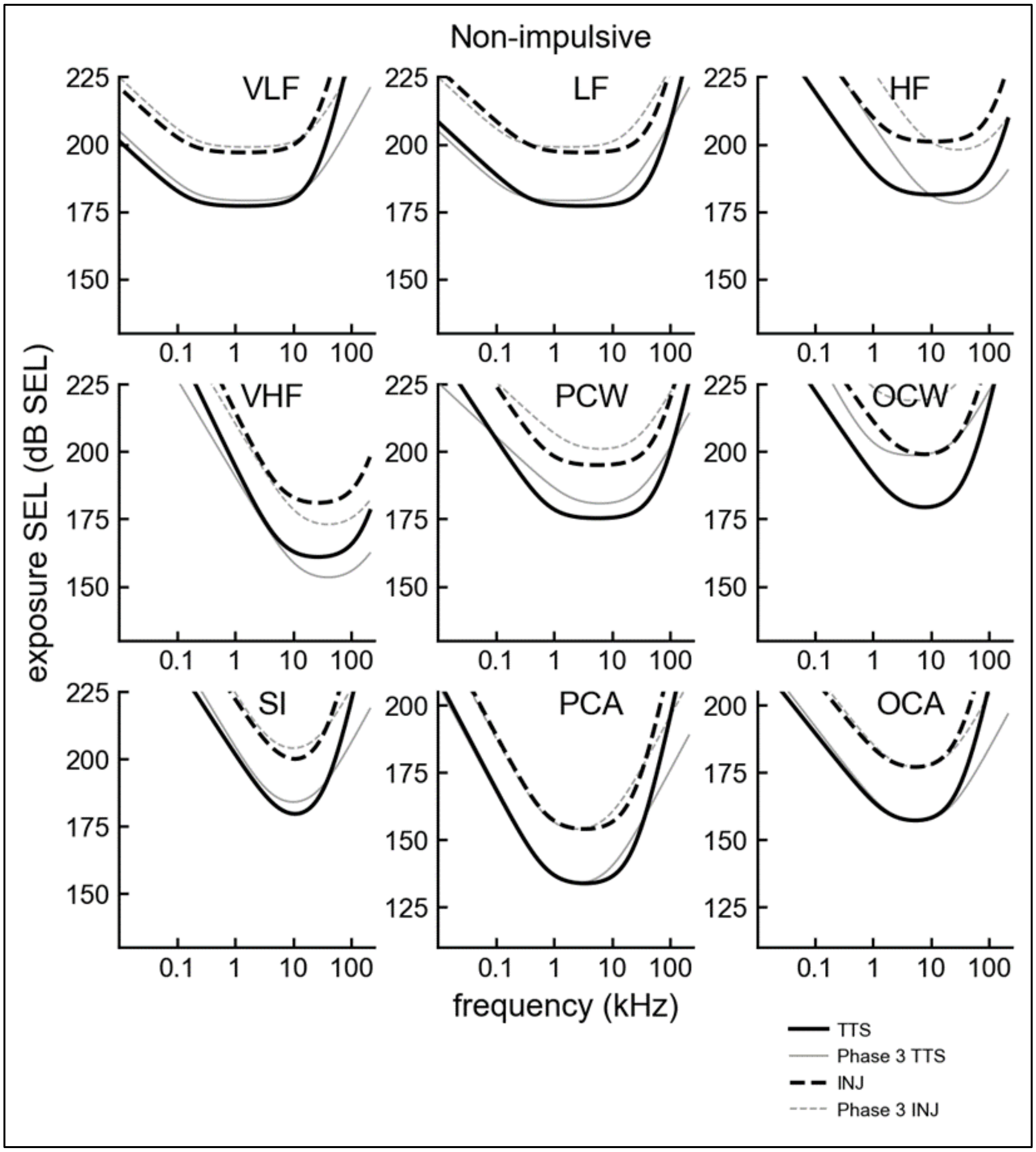
The auditory criteria and thresholds used in this analysis have been updated since the prior assessment of impacts due to military readiness activities in the Study Area. They incorporate new best available science since the release of NMFS guidance for assessing the effects of sound on marine mammal hearing (National Marine Fisheries Service, 2018a) and since the publication of recommendations by the expert panel on marine mammal auditory criteria (Southall et al., 2019).

The best way to illustrate frequency-dependent susceptibility to auditory effects is an exposure function. For each marine mammal auditory group, exposure functions for TTS and AINJ (previously called PTS, but now called AINJ to clarify that this is inclusive of neural injury) incorporate both the shape of the group's auditory weighting function and its weighted threshold value for either TTS or AINJ. The updated exposure functions and the exposure functions used in the prior analysis of impacts (Phase 3) are shown together in Figure 2.2-1 and Figure 2.2-2. Exposure functions for non-impulsive sounds are in Figure 2.2-1. Impulsive sounds are analyzed using two criteria, SEL and peak pressure. Figure 2.2-2 shows the exposure functions for the SEL-based criteria and Table 2.2-1 shows the peak pressure criteria used for impulsive sounds.

The auditory criteria and thresholds (described in the *Criteria and Thresholds TR*) underwent several notable changes from the prior analysis that influence estimates of the number of marine mammals that could be impacted in each training or testing event.

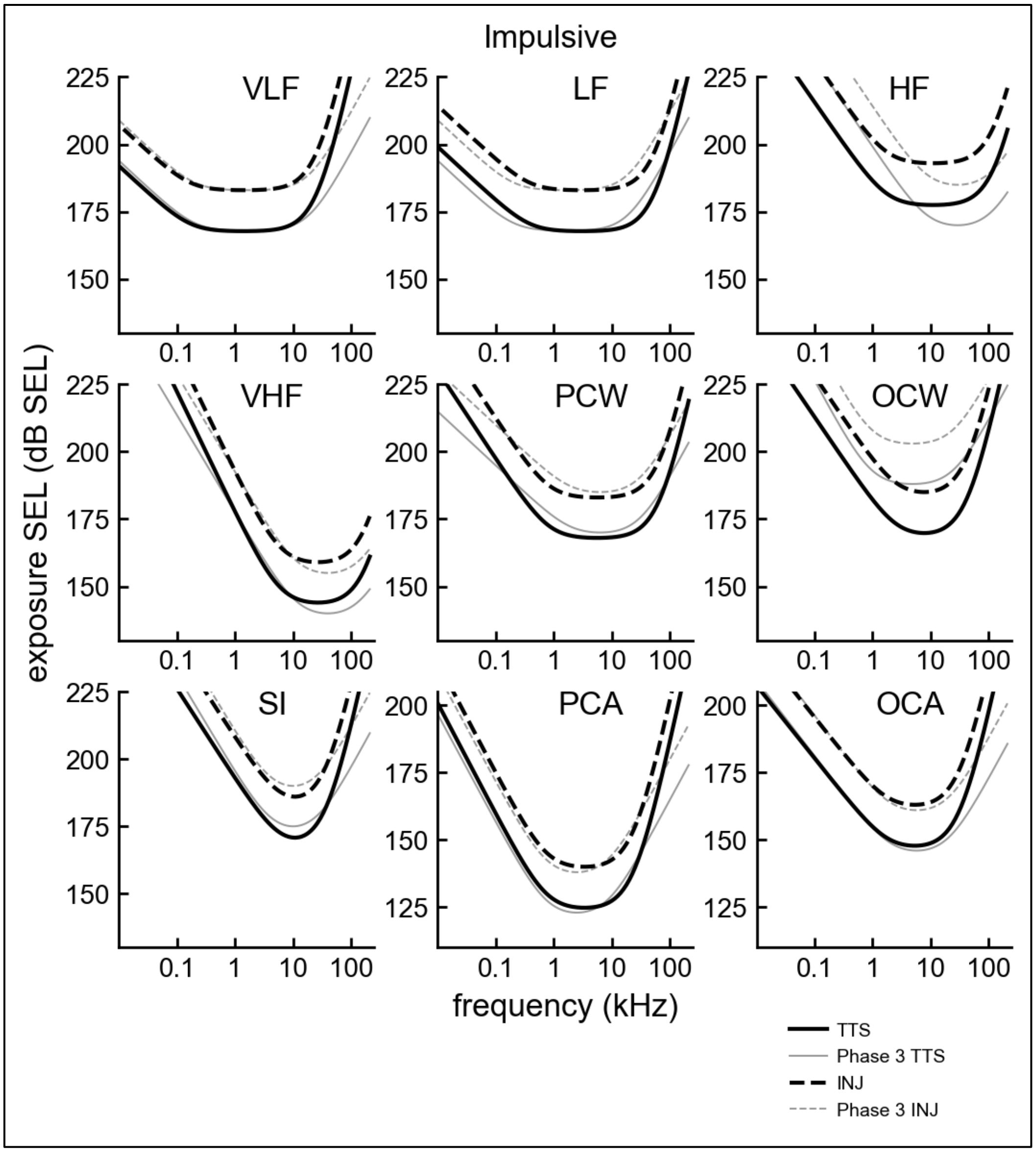
- The mysticetes have been split from one auditory group (the low frequency cetaceans, LF) into two auditory groups: the LF (including minke, humpback, gray, Rice's, Bryde's, and sei whales), and the very low frequency cetaceans, VLF (blue, fin, right, and bowhead whales). While the VLF auditory group retains similar susceptibility to auditory effects as the prior analysis, the new LF auditory group is predicted to be more susceptible to effects at higher frequencies and less susceptible to effects at lower frequencies. Consequently, for LF species, estimated auditory effects due to sources at frequencies above 10 kHz are substantially higher than in prior analysis of the same activities.

- The auditory group previously called the mid-frequency cetaceans (MF) is now called the high frequency cetaceans (HF). All species previously in the MF cetacean auditory group (most odontocetes) are now in the HF cetacean auditory group, and there is no MF cetacean exposure function. In the future, there may be sufficient data to support splitting the current HF cetacean auditory group into MF and HF auditory groups, with certain larger odontocetes (sperm, beaked, and killer whales) in the MF auditory group.
- The HF cetaceans are predicted to be much more susceptible to auditory effects at low and mid-frequencies than previously analyzed. Consequently, the estimated auditory effects due to sources under 10 kHz, including MF1 hull-mounted sonar and other anti-submarine warfare sonars, are substantially higher for this auditory group than in prior analyses of the same activities.
- The auditory group previously called the high frequency cetaceans (HF) is now called the very high frequency cetaceans (VHF). This auditory group, which includes harbor porpoises and Kogia whales, is predicted to be less susceptible to auditory effects at high frequencies (above 10 kHz) than previously analyzed. Consequently, estimated impacts on this group from high frequency sources is slightly lower than prior analyses of the same activities.
- The phocid carnivores (PCW) are predicted to be slightly more susceptible and otariids and other marine carnivores (OCW) are predicted to be substantially more susceptible to auditory effects across their hearing range than previously analyzed. Consequently, estimated auditory effects for PCW and OCW are higher than in prior analyses of the same activities.



Note: Auditory groups are very low frequency cetaceans (VLF), low frequency cetaceans (LF), high frequency cetaceans (HF), very high frequency cetaceans (VHF), phocid carnivores in water and air (PCW and PCA), otariids and other marine carnivores in water and in air (OCW and OCA), and sirenians (SI). SI are not in HCTT Study Area. Heavy solid lines —Phase 4 TTS exposure functions. Thin solid lines —Phase 3 TTS exposure functions. Heavy dashed lines —Phase 4 AINJ exposure functions. Thin dashed lines —Phase 3 AINJ exposure functions. Figure taken from U.S. Department of the Navy (2024a).

Figure 2.2-1: Marine Mammal TTS and AINJ Exposure Functions for Sonars and Other Non-Impulsive Sources



Note: Auditory groups are very low frequency cetaceans (VLF), low frequency cetaceans (LF), high frequency cetaceans (HF), very high frequency cetaceans (VHF), phocid carnivores in water and air (PCW and PCA), otariids and other marine carnivores in water and in air (OCW and OCA), and sirenians (SI). SI are not in HCTT Study Area. Heavy solid lines —Phase 4 TTS exposure functions. Thin solid lines —Phase 3 TTS exposure functions. Heavy dashed lines —Phase 4 AINJ exposure functions. Thin dashed lines —Phase 3 AINJ exposure functions. Figure taken from U.S. Department of the Navy (2024a).

Figure 2.2-2: Marine Mammal TTS and AINJ Exposure Functions for Impulsive Sources

Table 2.2-1: Peak SPL Thresholds for Auditory Impacts on Marine Mammals from Impulsive Sources

Hearing Group	TTS		AINJ		Change
	Phase 3	Phase 4	Phase 3	Phase 4	
VLF & LF	213	216	219	222	+3
HF	224	224	230	230	0
VHF	196	196	202	202	0
OCW	226	224	232	230	-2
PCW	212	217	218	223	+5

Note: values are unweighted peak pressures in dB re 1 µPa underwater. VLF = very low frequency cetacean, LF = low frequency cetacean, HF = high frequency cetacean, VHF = very high frequency cetacean, OCW = otariid in water, PCW = phocid in water.

The instances of AINJ and TTS predicted by the Navy Acoustic Effects Model are not reduced to account for activity-based mitigation in this analysis, unlike prior analyses. Still, it is likely that some model-predicted instances of AINJ and TTS would not occur during actual events using platforms and acoustic sources with applicable mitigation. If Lookouts sight a marine mammal within or entering a mitigation zone, the use of sonars, air guns, pile drivers, and explosives would be delayed, relocated, powered down, or ceased, as appropriate for the source as described in the *Mitigation* section. This would reduce an animal's sound exposure level or prevent an exposure that could cause hearing loss altogether.

The Navy Acoustic Effects Model estimates the reduction in cumulative sound exposure level due to marine mammal avoidance of high-level sonar exposures. Initiation of aversive behavior is based on the applicable behavioral response function for a species. Avoidance speeds and durations are estimated from baseline species data and actual sonar exposure data, when available. The estimated cumulative exposure level, including any reductions due to avoidance (if initiated), is compared to the thresholds for AINJ and TTS to assess auditory impacts. If the thresholds for AINJ or TTS are not exceeded, the potential for behavioral response is assessed based on the highest exposure in the simulation. This analysis assumes that a small portion (5 percent) of delphinids in the odontocete behavioral group would not avoid most events but would stay in the vicinity to engage in bow-riding or other behaviors near platforms (i.e., the cumulative sound exposure level is not reduced through avoidance). A detailed explanation of the new avoidance model and the species avoidance factors are in the *Quantitative Analysis TR (U.S. Department of the Navy, 2024b)*.

The ability to reduce cumulative sound exposure level depends on susceptibility to auditory effects, sensitivity to behavioral disturbance, and characteristics of the sonar source, including duty cycle, source level, and frequency. Table 2.2-2 shows the percentage reduction of AINJ across all the modeled activities in this analysis due to avoidance. The reduction in AINJ due to avoidance differs across activities and between auditory and behavioral groups. Groups that are relatively less sensitive to behavioral disturbance compared to susceptibility to auditory effects are less likely to avoid AINJ; these include the Mysticete and Odontocete behavioral groups. Groups that are relatively more sensitive to behavioral disturbance compared to susceptibility to auditory effects are more likely to avoid AINJ; these include the Sensitive Species and Pinniped behavioral groups. The reduction in AINJ for most groups is less than assumed in prior analyses[3] for most species except for beaked whales (High-Frequency cetacean auditory group and Sensitive Species behavioral group).

Table 2.2-2: Reduction in AINJ due to Avoiding Sonars in the Navy Acoustic Effects Model Across Activities

FHG	MYST	ODONT	SENS	PINN
VLF	14 - 20 %	-	-	-
LF	4 - 50 %	-	-	-
HF	-	67 - 96 %	96 - 100 %	-
VHF	-	44 - 46 %	87 - 87 %	-
PW	-	-	-	84 - 93 %
OT	-	-	-	78 - 95 %

version: 20241031

Recovery from TTS after a sound exposure is not quantified in this analysis (see the *Marine Mammal Acoustic Background* section). Small amounts of TTS (a few dB) typically begin to recover immediately after the sound exposure and may fully recover in minutes, while larger amounts of TTS require longer to recover. Most TTS fully recovers within 24 hours, but larger shifts could take days to fully recover. In general, TTS quantified based on SEL for intermittent sound exposures is likely over-estimated because some recovery from TTS may occur in the quiet periods between sounds, especially when the duty cycle is low. Lower duty cycles allow for more time between sounds and therefore more of an opportunity for hearing to recover. Modeled effects using the SEL-based criteria are therefore likely to accurately predict impacts from higher duty cycle sources and certainly overestimate impacts from lower duty cycle sources.

See Section 2.5 (Ranges to Effects) for information on the ranges to TTS and AINJ with distance based on the type of sound sources and hearing group, as well as several other factors.

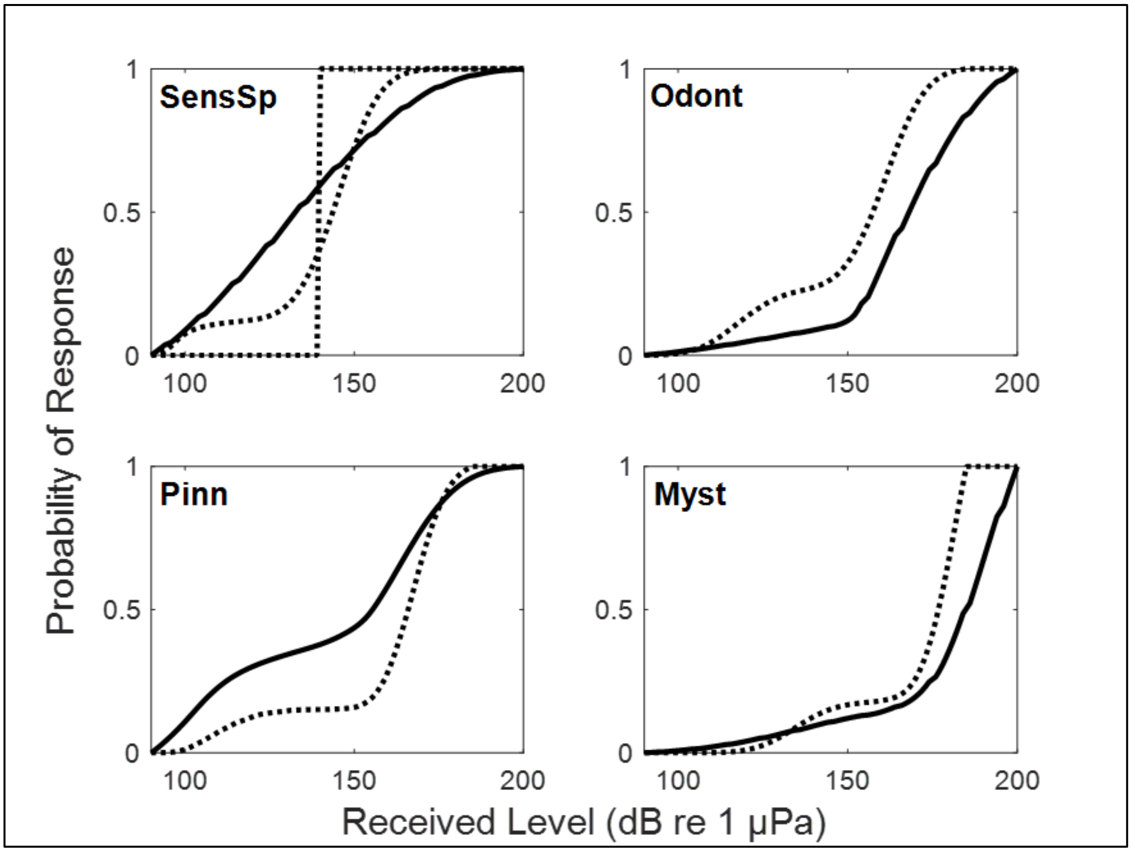
2.2.3 Quantifying Behavioral Responses to Sonars

Criteria and thresholds for behavioral responses have been updated since the prior analysis (see *Criteria and Thresholds TR*). Notable differences between the prior and updated criteria and thresholds for behavioral responses to sonars are as follows:

- Beaked whales and harbor porpoise are in a combined Sensitive Species behavioral group (previously, these groups had unique response functions). Other behavioral groupings remain the same: Mysticetes (all baleen whales), Odontocetes (most toothed whales, dolphins, and porpoises), and Pinnipeds (true seals, sea lions, walruses, polar bears).
- Behavioral cut-off conditions have been revised. The prior analysis only applied distance cut-offs. This analysis applies a dual cut-off condition based on both distance and received level. The cut-off distances have also been revised. These updates are described at the end of this section.

[3] In prior analyses, the reduction in AINJ due to avoidance was calculated outside of the Navy Acoustic Effects Model by applying a common reduction factor based on spreading loss from a hull-mounted sonar and assuming that all nearby animals would avoid the sound source (U.S. Department of the Navy, 2019). This resulted in reducing most NAEMO-predicted AINJ to TTS.

For each group, a biphasic behavioral response function was developed using best available data and Bayesian dose response models. The behavioral response functions are shown in Figure 2.2-3.



Notes: Revised behavioral response functions (solid lines) and prior behavioral response functions (Phase 3, dotted lines). SensSp = Sensitive Species, Odont = Odontocetes, Pinn = Pinnipeds, Myst = Mysticetes. Both the Phase 3 beaked whale behavioral response function and the Phase 3 harbor porpoise step function are plotted against the new Sensitive Species curve. Figure taken from U.S. Department of the Navy (2024a)

Figure 2.2-3: Behavioral Response Functions

Due to the addition of new data and the separation of some species groups, the most significant differences from prior analyses include the following:

- The Sensitive Species behavioral response function is more sensitive at lower received levels but less sensitive at higher received levels than the prior beaked whale and harbor porpoise functions.
- The Odontocete behavioral response function is less sensitive across all received levels due to including additional behavioral response research. This will result in a lower number of behavioral responses than in the prior analysis for the same event, but also reduces the avoidance of auditory effects.
- The Pinniped in-water behavioral response function is more sensitive due to including additional captive pinniped data. Only three behavioral studies using captive pinnipeds were available for the derivation of the behavioral response function. Behavioral studies of captive animals can be difficult to extrapolate to wild animals due to several factors (e.g., use of trained subjects). This means the

pinniped behavioral response function likely overestimates effects compared to observed reactions of wild pinnipeds to sound and anthropogenic activity.

- The Mysticete behavioral response function is less sensitive across most received levels due to including additional behavioral response research. This will result in a lower number of behavioral responses than in the prior analysis for the same event, but also reduces the avoidance of auditory effects.

The behavioral response functions only relate the highest received level of sound during an event to the probability that an animal will have a behavioral response. Currently, there are insufficient data to develop criteria that include the context of an exposure, characteristics of individual animals, behavioral state, duration of an exposure, sound source duty cycle, the number of individual sources in an activity, or how loud the animal may perceive the sonar signal to be based on the frequency of the sonar versus the animal's hearing range, although these factors certainly influence the severity of a behavioral response.

The behavioral response functions also do not account for distance. At moderate to low received levels the correlation between probability of reaction and received level is very poor and it appears that other variables mediate behavioral reactions (e.g., Ellison et al., 2011) such as the distance between the animal and the sound source. Data suggest that beyond a certain distance, significant behavioral responses are unlikely. At shorter ranges (less than 10 km) some behavioral responses have been observed at received levels below 140 dB re 1 µPa. Thus, proximity may mediate behavioral responses at lower received levels. Since most data used to derive the behavioral response functions is within 10 km of the source, probability of reaction at farther ranges is not well-represented. Therefore, the source-receiver range must be considered separately to estimate likely significant behavioral reactions.

This analysis applies behavioral cut-off conditions to responses predicted using the behavioral response functions. Animals within a specified distance and above a minimum probability of response are assumed to have a significant behavioral response. The cut-off distance is based on the farthest source-animal distance across all known studies where animals exhibited a significant behavioral response. Animals beyond the cut-off distance but with received levels above the sound pressure level associated with a probability of response of 0.50 on the behavioral response function are also assumed to have a significant behavioral response. The actual likelihood of significant behavioral reactions occurring beyond the distance cut-off is unknown. Significant behavioral responses beyond 100 km are unlikely based on source-animal distance and attenuated received levels. The behavioral cut-off conditions are shown in

Table 2.2-3. Additional information on the derivation of the cut-off conditions is in the *Criteria and Thresholds TR*.

Table 2.2-3: Phase IV Behavioral Cut-off Conditions for each Species Group

Behavioral Group	Received level associated with p(0.50) on the behavioral response function[1]	Cut-off Range[2]
Sensitive Species[1]	133 dB re 1 µPa	40 km
Odontocetes	168 dB re 1 µPa	15 km
Mysticetes	185 dB re 1 µPa	10 km
Pinnipeds	156 dB re 1 µPa	5 km

[1] A minimum p(response) condition was not applied in the prior Phase 3 analysis. [2] Distance cutoffs for moderate source level/single platform and high source level/multi-platform conditions in Phase 3: beaked whales (25/50 km), harbor porpoises (20/40 km), odontocetes (10/20 km), mysticetes (10/20 km), and pinnipeds 5/10 km).

See Section 2.5 (Ranges to Effects) for information on the probability of behavioral response with distance based on the type of sonar and behavioral group, as well as several other factors.

2.2.4 Quantifying Behavioral Responses to Air Guns, Pile Driving, and Explosives

Behavioral responses are quantified for air guns, pile driving (impact and vibratory), and explosions. These stressors are all impulsive sounds except for vibratory pile driving, which is a continuous, broadband non-impulsive sound. The thresholds used to quantify behavioral responses to air guns, pile driving, and explosions are described in the *Criteria and Thresholds TR* and are listed in Table 2.2-4. These thresholds are the same as those applied in the prior analysis of these stressors in the Study Area, although the explosive behavioral threshold has shifted, corresponding to changes in the TTS thresholds as explained below.

Table 2.2-4: Behavioral Response Thresholds for Air Gun, Pile Driving, and Explosive Sounds

Sound Source	Behavioral Threshold
air gun	160 dB rms re 1 µPa SPL
impact pile driving	160 dB rms re 1 µPa SPL
vibratory pile driving	120 dB rms re 1 µPa SPL
multiple explosions	5 dB less than the TTS onset threshold (weighted SEL)
single explosions or one cluster	TTS onset threshold (weighted SEL)

While seismic and pile driving data provide the best available science for assessing behavioral responses to impulsive sounds by marine mammals, it is likely that these responses represent a worst-case scenario compared to responses to explosives used in military readiness activities, which would typically consist of single impulses or a cluster of impulses (i.e., acute sounds), rather than long-duration, repeated impulses (i.e., potentially chronic sounds).

For single explosions at received sound levels below hearing loss thresholds, the most likely behavioral response is a brief alerting or orienting response. Since no further sounds follow the initial brief impulses, significant behavioral reactions would not be expected to occur. If a significant response were to occur, this analysis assumes it would be within the range of auditory impacts (AINJ and TTS). This reasoning was applied to previous shock trials and is extended to the criteria used in this analysis. Because of this approach, the number of auditory impacts is higher than the number of behavioral impacts in the quantified results for some stocks.

If more than one explosive event occurs within any given 24-hour period within a military readiness activity, criteria are applied to predict the number of animals that may have a behavioral reaction. For events with multiple explosions, the behavioral threshold used in this analysis is 5 dB less than the TTS onset threshold. This value is derived from observed onsets of behavioral response by test subjects (bottlenose dolphins) during non-impulse TTS testing (Schlundt et al., 2000).

See Section 2.5 (Ranges to Effects) for information on the behavioral response distances from these stressors.

2.2.5 Quantifying Non-Auditory Injury due to Explosives

The criterion for mortality is based on severe lung injury observed in terrestrial mammals exposed to underwater explosions as recorded in Goertner (1982). The criteria for non-auditory injury are based on slight lung injury or gastrointestinal tract injury observed in the same data set. Mortality and slight lung injury impacts on marine mammals are estimated using impulse thresholds based on both calf/pup/juvenile and adult masses (see *Criteria and Thresholds TR*). The peak pressure threshold applies to all species and age classes. Unlike the prior analysis, this analysis relies on the onset rather than the mean estimated threshold for these effects. This revision results in a small increase in the predicted non-auditory injuries and mortalities for the same event versus prior analyses. Thresholds are provided in Table 2.2-5 for use in non-auditory injury assessment for marine mammals exposed to underwater explosives.

Table 2.2-5: Thresholds for Estimating Ranges to Potential Effect for Non-Auditory Injury

Effect	Threshold
Onset Mortality - Impulse	$103M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Impulse (Non-auditory)	$47.5M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Peak Pressure (Non-auditory)	237 dB re 1 µPa peak

Where M is animal mass (kg) and D is animal depth (m).

See Section 2.5 (Ranges to Effects) for information on the distance to which non-auditory injury and mortality would extend from a detonation based on the size of the explosion, the marine mammal species, as well as several other factors.

2.3 Assessing Impacts on Individuals and Populations

2.3.1 Severity of Behavioral Responses to Military Readiness Activities

The statutory definition of Level B harassment of marine mammals for military readiness activities is the “disruption of natural behavioral patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioral patterns are abandoned or significantly altered” (Section 3(18)(B) of the MMPA)). The terms “significant response” or “significant behavioral response” are used to describe behavioral reactions that may lead to an abandonment or significant alteration of a natural behavior pattern. Defining when a behavioral response becomes significant, as well as setting corresponding predictive exposure threshold values, is challenging. Whether an animal discernably responds, and the severity of that response are likely influenced by the animal's life experience, motivation, and conditioning; the physical condition of the animal; and the context of the exposure (Ellison et al. 2015, Southall et al. 2007, Southall et al. 2019).

Behavioral responses can be generally categorized as low, moderate, or high severity. Low severity responses are within an animal's range of typical (baseline) behaviors and would not be considered significant. High severity responses are those with a higher likelihood of consequences to growth, survival, or reproduction, such as behaviors that increase the risk of injury, prolonged separation of a female and dependent offspring, prolonged displacement from foraging areas, or prolonged disruption of breeding behavior. High severity reactions would always be considered significant, even if no direct negative outcome is observed. For example, separation of a killer whale mother-calf pair was observed when they were approached by a vessel with an active sonar source during a behavioral response study (Miller et al., 2014), but the animals rejoined once the ship passed.

Stranding is a very high severity response. Use of mid-frequency sonar has been associated with atypical mass strandings of beaked whales (Bernaldo de Quirós et al., 2019; D'Amico et al., 2009). Five stranding events, mostly involving beaked whales, have been attributed to U.S. Navy active sonar use. The confluence of factors that contributed to those strandings is now better understood (see the *Background* section), and U.S. Navy sonar has not been identified as a causal factor in an atypical mass stranding since 2006. Other high severity responses have not been observed during observations of actual training or testing activities. The Navy does not anticipate that marine mammal strandings or mortality will result from the operation of sonar during military readiness activities in the study area. Through adaptive management under the MMPA, NMFS and the Navy will determine the appropriate way to proceed if a causal relationship were to be found between Navy activities and a future stranding.

The behavioral responses predicted in this analysis are likely moderate severity within the scale presented in Southall et al. (2021b). Examples of moderate severity responses include avoidance, changes in vocalization, reduced foraging, reduced surfacing, and changes in courtship behavior. If moderate behaviors are sustained long enough to be outside of normal daily variations in feeding, reproduction, resting, migration/movement, or social cohesion, they are considered significant.

Given the available data on marine mammal behavioral responses, this analysis errs toward overestimating the number of significant behavioral responses. It is not possible to ascertain the true significance of most observed reactions that underlie the behavioral response functions used in this analysis. The behavioral criteria assume that most reactions that lasted for the duration of a sound exposure or longer were significant, regardless of exposure duration. It is possible that some short duration responses would not rise to the level of harassment as defined above. In addition, the experimental designs used during some behavioral response studies with non-captive animals were unlike military readiness activities in important ways. These differences include closely approaching and tagging subject animals; following subjects before the exposure; vectoring towards avoiding animals; or multiple close passes by focal animal groups. In contrast, military platforms would not purposely undertake such close approaches nor make directed movements toward animals. As researchers have improved experimental designs in subsequent behavioral response studies, more recent data better reflects responses in contexts more closely matching exposures during military readiness activities. Interpreting studies with captive animals presents other challenges, as captive animals may have different behavioral motivations than non-captive animals, and the context of exposure (confined environment, distance from source) differs from non-captive exposures. Thus, some behavioral reactions associated with acoustic received levels then used to develop behavioral risk functions may have been influenced by other aspects of the experimental exposures.

2.3.2 Potential Opportunities to Mitigate Auditory and Non-Auditory Injury

Visual observation of mitigation zones and nearby sea space is prescribed in the section *Mitigation*. In summary, trained Lookouts would be positioned on surface vessels, aircraft, piers, or the shore to observe designated mitigation zones around stressors prior to and during the use of certain sound sources and explosives. The specified mitigation zones are the largest areas Lookouts can reasonably be expected to observe during typical activity conditions, while being practical to implement from an operational standpoint. When a marine mammal (and in some instances, indicators of marine mammal presence like floating concentrations of vegetation) is sighted within or entering a mitigation zone, sound-producing activities are delayed, relocated, powered down, or ceased. These actions either reduce an acoustic dose (in the case of an ongoing acoustic stressor) or prevent an injurious exposure altogether (in the case of a single exposure like an explosion).

Ranges to auditory effects (AINJ and TTS) for marine mammals exposed to sonars are in Section 2.5.1 (Ranges to Effects for Sonar and Other Transducers) for the following sonars: hull-mounted surface ship sonar (bins MF1, MF1C, and MF1K), helicopter dipping sonar, sonobuoy sonar, and towed mine-hunting sonar. The median ranges to AINJ for all hearing groups due to hull-mounted sonars are encompassed by the applicable mitigation zones (200 yd. shut down/500 yd. power down/1,000 yd. power down). The median ranges to AINJ for all hearing groups for the remaining sonar are encompassed by the applicable mitigation zone (200 yd. shut down). Ranges to mortality for marine mammal exposed to in-water explosions are in Section 2.5.4 (Ranges to Effects for Explosives) for all bins. Mitigation ranges for explosives differ depending on the type of activity. In all cases, the mitigation zones encompass the ranges to mortality for the bin sizes that may be used.

Although the mitigation zones cover the range to AINJ for most sonar sources in most conditions, this analysis does not reduce model-predicted impacts on account for visual observations. Instead, the Navy Acoustic Effects Model identified the number of instances that animats with doses exceeding thresholds for AINJ (sonar) also had their closest points of approach within applicable mitigation zones. These instances are considered potential mitigation opportunities, which would be further influenced by other factors such as the sightability of the species and viewing conditions, as discussed in the *Mitigation* section. These instances were only assessed using the applicable mitigation zone size for platforms and sources with visual observation requirements. The closest point of approach considers any predicted animal avoidance of a sound source in the activity.

The results for activities that use sonar and have at least one model-predicted AINJ in any of the marine mammal auditory groups are shown in Table 2.3-1. Activities that have no predicted auditory injuries (following the rounding rules presented below, under Section 2.4 [Species Impact Assessments]) are not shown in Table 2.3-1. The mixed results across activities are due to a variety of factors. Some scenarios under each activity may include platforms or sources that do not have applicable visual observation requirements. Other activities may occur in locations where there are low numbers of animals in an auditory group; thus, the ratio is sensitive to the limited number of instances modeled. Most auditory injuries to the HF cetacean auditory group have an associated closest point of approach in a mitigation zone. Some of these will be observed and the exposure minimized or avoided because of mitigation. A portion (5 percent) of the auditory group was assumed to not avoid in the model to account for close approach behaviors like bow-riding. In an actual event, if delphinids were observed bow-riding, the activity could continue without powering down or ceasing the sonar, as described in the *Mitigation* section.

Table 2.3-1: Potential Mitigation Opportunities During Activities with Sonar

Activity Name	VLF	LF	HF	VHF	PCW	OCW
Acoustic and Oceanographic Research (ONR)	45%	46%	44%	62%	11%	30%
Airborne Dipping Sonar Minehunting Test	-	-	-	100%	-	-
Anti-Submarine Warfare Mission Package Testing	100%	100%	100%	100%	-	100%
Anti-Submarine Warfare Torpedo Exercise - Helicopter	100%	-	-	-	-	-
Anti-Submarine Warfare Torpedo Exercise - Ship	100%	100%	100%	99%	100%	100%
Anti-Submarine Warfare Torpedo Test (Aircraft)	-	100%	-	-	-	-
Anti-Submarine Warfare Tracking - Unmanned Vehicles (USMC)	100%	-	100%	100%	-	-
Anti-Submarine Warfare Tracking Exercise - Ship	96%	100%	100%	98%	100%	100%
At-Sea Sonar Testing	97%	96%	100%	77%	100%	100%
Civilian Port Defense	-	27%	91%	75%	100%	-
Composite Training Unit Exercise (Amphibious Ready Group/Marine Expeditionary Unit)	100%	100%	100%	100%	-	100%
Composite Training Unit Exercise (Strike Group)	100%	100%	100%	99%	100%	100%
Countermeasure Testing	-	100%	100%	56%	-	-
Innovation and Demonstration Exercise	100%	99%	100%	87%	100%	100%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	49%	85%	0%	73%	100%	0%
Medium Coordinated Anti-Submarine Warfare	100%	100%	100%	97%	100%	100%
Mine Countermeasures - Mine Neutralization - Remotely Operated Vehicles	-	-	-	100%	-	-
Mine Countermeasures - Ship Sonar	-	-	-	74%	-	-
Multi-Domain Unmanned Autonomous Systems	-	-	100%	96%	100%	-
Multi-Warfare Exercise	100%	100%	100%	93%	100%	100%
Pierside Sonar Testing	-	-	-	-	-	100%
Rim of the Pacific Exercise	100%	100%	100%	100%	-	-
Semi-Stationary Equipment Testing	-	-	100%	11%	-	-
Signature Analysis Operations	-	-	-	100%	-	-
Small Joint Coordinated Anti-Submarine Warfare	100%	100%	100%	92%	100%	100%
Submarine Navigation	-	-	-	100%	-	-
Submarine Sonar Maintenance and Systems Checks	-	-	0%	-	-	100%
Surface Ship Sonar Maintenance and Systems Checks	-	100%	100%	94%	-	100%
Surface Ship Sonar Testing/Maintenance (NAVSEA)	-	-	100%	64%	-	-
Surface Warfare Testing	-	-	-	1%	-	-
Surface Warfare Torpedo Exercise - Submarine	-	-	-	27%	-	-
Task Force/Sustainment Exercise	100%	100%	100%	97%	100%	100%
Torpedo (Explosive) Testing	-	-	-	41%	-	-
Torpedo (Non-Explosive) Testing	-	100%	96%	24%	-	100%
Training and End-to-End Mission Capability Verification - Torpedo	-	-	-	35%	-	-
Undersea Range System Test	-	-	-	100%	-	-
Undersea Warfare Testing	100%	100%	100%	99%	100%	100%
Unmanned Underwater Vehicle Testing	-	-	-	100%	-	-
Unmanned Underwater Vehicle Training - Certification and Development	-	-	-	84%	-	-
Vehicle Testing	100%	100%	86%	20%	-	15%

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Similarly for explosives, this analysis does not reduce model-predicted impacts on account for visual observations, even though the mitigation zones cover the range to mortality. For this Proposed Action, all predicted instances of mortality occurred within the associated mitigation zones for each type of explosive. Therefore, the predicted instances of mortality are over-estimated, as it is likely that some animals in the mitigation zone will be observed, especially for species that are highly visible such as delphinids in pods and for activities with nearby lookouts, and the exposure avoided, as described in *Mitigation.* If mortalities are predicted for any stock, the likely causal activity is identified in this analysis and associated mitigation identified. Based on the ranges to effect for explosives, most of the predicted non-auditory injuries would also occur within the applicable mitigation zones.

All instances of AINJ caused by air guns are predicted to occur within the mitigation zone (200 yd.).

2.3.3 Behavioral Responses by Distance and Sound Pressure Level

Figure 2.3-1 and Figure 2.3-2 provide the total number of predicted behavioral responses under a maximum year of activities for each behavioral response group (i.e., Odontocetes, Mysticetes, Pinnipeds, and Sensitive Species) across all activities and all sonar sources without applying TTS or AINJ thresholds. In other words, in these plots, behavioral response functions were applied to all animats in the Navy's acoustic effects model, assuming animals that did receive TTS or AINJ would also be likely to exhibit a behavioral response. For these two figures, the total bar height represents the total number of behavioral responses as indicated on the vertical axis, whereas the dark gray bars indicate the number of *significant* behavioral responses as defined for military readiness activities using the distance and probability of response cut-off conditions described at the end of Section 2.2.3 (Quantifying Behavioral Responses to Sonars) and presented in Table 2.2-3 for each behavioral response group.

Figure 2.3-1 shows the total number of behavioral responses in 6-dB SPL bins representing the highest received SPL. All exposures equal to or above the received level associated with p(0.50) on the applicable behavioral response function are assumed to be significant in this analysis. A portion of behavioral responses predicted at lower received levels (as low as 100 dB SPL) are also assumed to be significant. These exposures are due to sources with lower source levels while within the cutoff ranges in Table 2.2-3. Overall, there are few exposures to sonar above 200 dB SPL.

Figure 2.3-2 shows the total number of behavioral responses in 5-km bins. For odontocetes and mysticetes, few significant behavioral responses are estimated beyond the cutoff ranges in Table 2.2-3, which are 15 km and 10 km, respectively. For pinnipeds, all behavioral responses within 5 km are assumed to be significant. Some significant behavioral responses for higher source level sonars are predicted out to and beyond 50 km. All behavioral responses within 40 km are assumed to be significant for sensitive species, with some significant responses predicted as far as 100 km for the highest-level sonar sources. For mid-frequency bins in open ocean, there is a strong convergence zone between 50 km – 60 km and a second convergence zone starting beyond 95 km. This explains the spike in predicted behavioral responses at these distances in this Study Area.

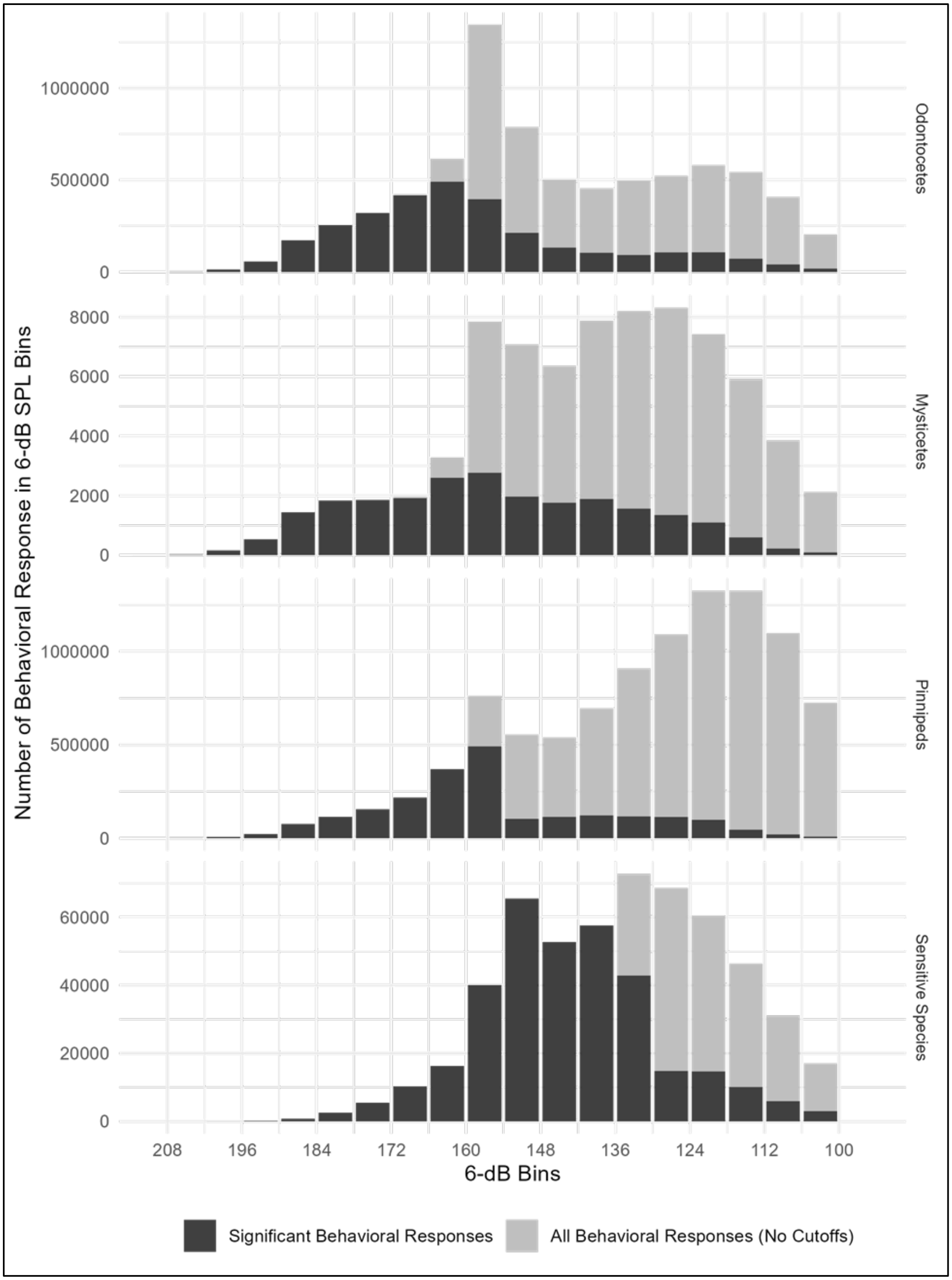

Figure 2.3-1: Total Predicted Instances of Marine Mammal Behavioral Responses in the Study Area by Received Level

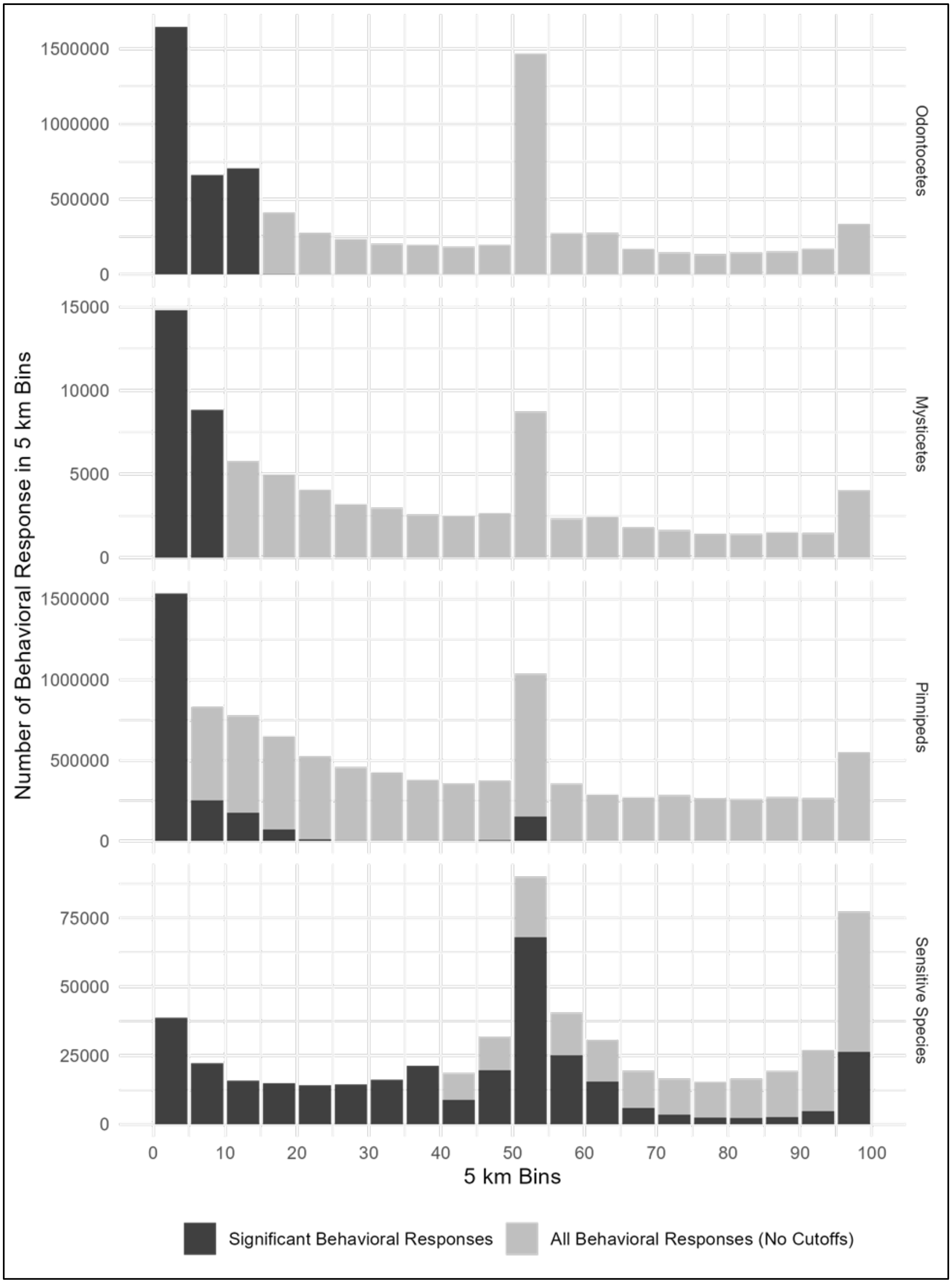

Figure 2.3-2: Total Predicted Instances of Marine Mammal Behavioral Responses in the Study Area by Distance

2.3.4 Risks to Marine Mammal Populations

To issue a Letter of Authorization under the MMPA, NMFS must determine that an impact "cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival." Assessing the consequences to a marine mammal population due to individual, short-term responses can be difficult and has been the subject of many studies.

Given the scope of the Proposed Action and the current state of the science regarding marine mammals, there is no known method to determine or predict the age, sex, or reproductive condition of the various species of marine mammals predicted to be impacted because of the proposed training and testing.

This analysis adapts the assessment of species vulnerability described in Southall et al. (2023). The relativistic risk assessment approach in Southall et al. (2023) was designed to compare risk to populations from specific industry impact scenarios at different locations or times of year. This approach may not be suitable for many military readiness activities, for which alternate spatial or seasonal scenarios are not usually feasible. However, the concepts considered in that framework's population vulnerability assessment are useful in this analysis, including population status (endangered or threatened), population trend (decreasing, stable, or increasing), population size, and chronic exposure to other anthropogenic or environmental stressors. These stock vulnerability factors are provided for every stock in the Study Area in Table 2.3-4 for ESA-listed species and in Table 2.3-5 for species that are not ESA-listed.

This analysis also relies on the population consequences of disturbance themes identified in Keen et al. (2021). These themes fall into three categories: *life history traits, environmental conditions, and disturbance source characteristics*.

Life history trait definitions used in this analysis are shown in Table 2.3-2. Life history traits include:

- Movement ecology (resident/nomadic/migratory): Resident animals that have small home ranges relative to the size and duration of an impact zone would have a higher risk of repeated exposures to an ongoing activity. Animals that are nomadic over a larger range may have less predictable risk of repeated exposure. For resident and nomadic populations, overlap of a stressor with feeding or reproduction depend more on time of year rather than location in their habitat range. In contrast, migratory animals may have higher or reduced potential for exposure during feeding and reproduction based on both location, time of the year, and duration of an activity. The risk of repeated exposure during individual events may be lower during migration as animals maintain directed transit through an area.
- Reproductive strategy (capital/income/mixed): Reproduction is energetically expensive for female marine mammals. Mysticetes and phocids are capital breeders. Capital breeders rely on their capital, or energy stores, to migrate, maintain pregnancy, and nurse a calf. Capital breeders would be more resilient to short-term foraging disruption due to their reliance on built-up energy reserves. Otariids and most odontocetes are income breeders, which rely on some level of income, or regular foraging, to give birth and nurse a calf. Income breeders would be more sensitive to the consequences of disturbances that impact foraging during lactation. Some species exhibit traits of both, such as beaked whales.
- Body size (small/medium/large): Smaller animals require more food intake per unit body mass than large animals. They must consume food on a regular basis and are likely to be non-migratory and

income breeders. The smallest odontocetes, the porpoises, must maintain high metabolisms to maintain thermoregulation and cannot rely on blubber stores for long periods of time, whereas larger odontocetes can more easily thermoregulate. The larger size of other odontocetes is an adaptation for deep diving that allows them to access high quality mesopelagic and bathypelagic prey. Both small and large odontocetes have lower foraging efficiency than the large whales. The filter-feeding large whales (mysticetes) consume most of their food within several months of the year and rely on extensive lipid reserves for the remainder of the year. The metabolism of mysticetes allows for fasting while seeking prey patches during foraging season and prolonged periods of fasting outside of foraging season (Goldbogen et al., 2023). Their energy stores support capital breeding and long migrations. The effect of a temporary feeding disturbance is likely to have inconsequential impacts on a mysticete but may be consequential for small cetaceans. Despite their relatively smaller size, amphibious pinnipeds have lower thermoregulatory requirements because they spend a portion of time on land. For purposes of this assessment, marine mammals were generally categorized as small (less than 10 ft.), medium (10-30 ft.), or large (more than 30 ft.) based on length.

- Pace of life (slow/medium/fast): Populations with a fast pace of life are characterized by early age of maturity, high birth rates, and short life spans, whereas populations with a slow pace of life are characterized by later age of maturity, low birth rates, and long life spans. The consequences of disturbance in these populations differ. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations are quick to recover. Reproduction in populations with a slow pace of life is resilient to foraging disruption, but late maturity and low birth rates mean that long-term impacts on breeding adults have a longer-term effect on population growth rates. The discussion of “generation times” in the species impact analyses below are referring to that species’ age of maturity. Pace of life was categorized for each species in this analysis by comparing age at sexual maturity, birth rate interval, life span, body size, and feeding and reproductive strategy. Pace of life attribute definitions are shown in Table 2.3-3.

The above life history traits are identified for each NMFS-designated stock in the Study Area in Table 2.3-4 for ESA-listed species and in Table 2.3-5 for all other stocks in the Study Area. If a species or stock has life history trait characteristics that span two classifications, both are shown (e.g., if a species exhibits both resident and nomadic behavior, it is described as resident-nomadic in the table).

Table 2.3-2: Life History Characteristic Definitions

Life History Characteristic	Body Size	Feeding/Breeding Strategy	Pace of Life	Chronic Anthropogenic Risk Factors	Chronic Biological Risk Factors (Non-Noise)
Categories/ Definitions	[Small, Medium, Large]	[Capital, Income, Intermediate/ Mixed]	[Fast, Medium, Slow]	Risk from anthropogenic stressors (e.g., acoustic, fisheries interactions, vessel strike)	Presence of disease, parasites, prey limitations, or high predation
Source of Information	Keen et al. (2021)	Keen et al. (2021)	Keen et al. (2021)	SAR, Best Available Science, NMFS Species Profiles	SAR, Best Available Science, NMFS Species Profiles
Definitions	Small: <3 m Medium: 3 - 9 m Large: > 9 m	Capitol breeder- stores energy prior to parturition for lactation Income Breeder- feeds during lactation	See Table 2.3-3	Environmental factors outside of Action Proponent's noise-generating activities. Increased prevalence of third-party stressors may increase species-specific vulnerability to the potential disturbance (Southall et al., 2021a).	

Notes: < = less than; > = more than; NMFS = National Marine Fisheries Service; SAR= stock assessment report

Table 2.3-3: Pace of Life Attribute Definitions

Attribute[1]	Definitions		
	Fast	Medium	Slow
Body Size	Small	Medium	Large
Birth Rate Interval	1 to 2 years	2 to 3 years	3+ years
Sexual Maturity[2]	Up to 3.75 years on average	3.75 to 7 years on average	7+ years on average
Lifespan	Up to 29 years	29 to 50 years	50+ years
Pace of Life Overall	Majority (3+) fast attributes	Majority medium[3]	Majority (3+) slow attributes

[1] Attribute citations NMFS 2023, Keen et al. 2021
[2] If sexual maturity was reported as a range for a particular species, an average value was used.
[3] If there was not an equal number of attributes, justification based on body size and birth rate interval was used to make final category decision. For example, most pinniped species were an even mix of small, medium, and fast attributes. However, with their overall small body size and birth rate interval of one year, it was determined that they fall in the "fast" Pace of Life category overall.
Note: + = or more

Environmental conditions include external anthropogenic and biological risk factors (not associated with the proposed activities) that can stress individuals and populations, making them more susceptible to long-term consequences. These factors include fisheries interactions, pollution, climate change, vessel strike, and other anthropogenic noise sources. These additional stressors are also considered when assessing the overall vulnerability of a stock to repeated effects from acoustic and explosive stressors.

Disturbance source characteristics include overlap with biologically important habitats, the duration and frequency (how often it occurs) of disturbance, and the nature and context of the exposure. In this analysis, disturbance source characteristics are considered as follows:

- The numbers and types of effects are estimated in areas that are (1) designated critical habitats for ESA-listed species and (2) Biologically Important Areas (BIAs), which are reproductive, feeding, and migration areas, and areas in which small and resident populations are concentrated (see the Marine Mammal Background for additional details). BIAs are specific to species and time of year and have no inherent regulatory authority. BIAs frequently overlap with designated critical habitat for ESA-listed species but may provide additional seasonal delineations for reproduction, feeding, or migration. They may also be hierarchical in that a larger “parent” BIA encompasses a smaller “child” BIA which often represents a higher use area.
- Information about the context of exposures can be obtained through the current exposure modeling process, including season, location of the activity, the distance from an acoustic source where an exposure threshold is exceeded, and the type of activity that resulted in modeled impacts.
- To obtain an estimate of the average number of times individual marine mammals within each stock may be affected annually, the total number of non-injurious (i.e., behavioral response, TTS) and injurious effects (i.e., AINJ, INJ, Mortality) are considered versus the population abundance.
- Activities that occur on instrumented ranges and within homeports, and long duration activities, such as major training exercises, require special consideration due to the potential for more frequent repeated impacts on individuals as compared to individuals living outside areas where military readiness activities may be concentrated.

Table 2.3-4: Stock Vulnerability Factors and Life History Traits for ESA-listed Marine Mammal Stocks within the Study Area

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
Blue whale	Eastern North Pacific	Migratory	Large	Capital	Slow	Unk, but possibly increasing	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Blue whale	Central North Pacific	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
False killer whale	Main Hawaiian Islands Insular	Resident-nomadic	Med	Income	Med	Appears to be decreasing	Fisheries interactions, contaminants	Climate change
Fin whale	California, Oregon, and Washington	Migratory-resident (SOCAL)	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Fin whale	Hawaiian	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Gray whale	Western North Pacific	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise, subsistence hunting	Climate change
Humpback whale	Central America/ Southern Mexico - California – Oregon – Washington (Central America DPS)	Migratory	Large	Capital	Slow	Increasing	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Humpback whale	Mainland Mexico - California – Oregon – Washington (Mexico DPS)	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Killer whale	Eastern North Pacific Southern Resident	Resident- nomadic	Large	Income	Slow	Decreasing	Fisheries interactions, vessel strikes, ocean noise, limitation of preferred Chinook salmon prey, contaminants, disturbance from high levels of boat traffic (including whale watch, recreational, and commercial vessels)	Climate change
Sei whale	Eastern North Pacific	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, ocean noise	Climate change

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
Sei whale	Hawaii	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, ocean noise	Climate change
Sperm whale	California, Oregon, and Washington	Migratory-resident	Large	Income	Slow	Unk, but possibly stable	Vessel strikes, fisheries interactions, ocean noise, marine debris, disease	Climate change
Sperm whale	Hawaii	Resident-migratory	Large	Income	Slow	Unk	Vessel strikes, fisheries interactions, ocean noise, marine debris, disease	Climate change
Hawaiian Monk Seal	Hawaiian	Resident	Small	Capital	Fast	Stable/ increasing	Fisheries interactions, illegal harassment, habitat degradation	Disease
Guadalupe Fur Seal	Mexico to California	Migratory	Small	Income	Fast	Increasing	Fisheries interactions, intentional illegal killing/harassment	Unknown
Southern Sea Otter	California Stock	Resident	Small	Income	Fast	Stable	Fisheries interactions, vessel strike, illegal killing	Disease, harmful algal blooms, predation

Notes: Unk = unknown, Med = medium

[1] Stock designations are from Pacific and Alaska Stock Assessment Reports prepared by NMFS (Carretta et al., 2023; Young, 2023) and the Sea Otter Stock Assessment Report prepared by USFWS (U.S. Fish and Wildlife Service, 2021).

[2] Fisheries interactions represents entanglement in fishing gear, including derelict fishing gear, and bycatch.

Table 2.3-5: Stock Vulnerability Factors and Life History Traits for non-ESA-listed Marine Mammal Stocks within the Study Area

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
Baird's beaked whale	California, Oregon, and Washington	Nomadic, resident	Large	Mixed	Slow	Stable, possibly increasing	Fisheries interactions, ocean noise	Climate Change
Blainville's beaked whale	Hawaii	Nomadic, resident	Med	Mixed	Med	Unk	Fisheries interactions, ocean noise	Disease, climate change
Bryde's whale	Eastern Tropical Pacific	Unknown, likely migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Bryde's whale	Hawaii	Unknown, likely migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
California sea lion	U.S. Stock	Resident-migratory	Small	Income	Fast	Stable	Fisheries interactions, power plant entrainment, illegal harassment,	Climate change, El Niño, harmful algal blooms

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
							habitat degradation, vessel strike, chemical contaminants	
Common bottlenose dolphin	California Coastal	Nomadic	Small-Med	Income	Med	Stable, potentially increasing	Biotoxins, chemical contaminants, fisheries interactions, habitat alteration, illegal feeding and harassment, ocean noise, oil spills and energy exploration, vessel strikes	Disease, climate change
Common bottlenose dolphin	California, Oregon, and Washington Offshore	Nomadic	Small-Med	Income	Med	Unk	Fisheries interactions	Climate change
Common bottlenose dolphin	Hawaiian Pelagic	Nomadic	Small-Med	Income	Med	Unk	Fisheries interactions	Disease, climate change
Common bottlenose dolphin	Kauai and Niihau	Resident	Small-Med	Income	Med	Unk	Fisheries interactions	Disease, climate change
Common bottlenose dolphin	Oahu	Resident	Small-Med	Income	Med	Unk	Entanglement	Disease, climate change
Common bottlenose dolphin	Maui Nui (formerly4-Islands)	Resident	Small-Med	Income	Med	Unk	Entanglement	Disease, climate change
Common bottlenose dolphin	Hawaii Island	Resident	Small-Med	Income	Med	Unk	Fisheries interactions	Disease, climate change
Goose-beaked (Cuvier's) whale	California, Oregon, and Washington	Nomadic, resident	Med	Mixed	Med	Unk	Fisheries interactions, ocean noise	Climate Change
Goose-beaked (Cuvier's) whale	Hawaii	Nomadic, resident	Med	Mixed	Med	Unk	Fisheries interactions, ocean noise	Disease, climate change
Dall's porpoise	California, Oregon, and Washington	Nomadic	Small	Income	Fast	Unk but likely stable	Fishing gear fisheries interactions	Climate change
False killer whale	Hawaii Pelagic	Nomadic	Med	Income	Med	Unk	Fisheries interactions, contaminants	Climate change

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
False killer whale	Northwestern Hawaiian Islands	Resident, nomadic	Med	Income	Med	Unk	Fisheries interactions, contaminants	Climate change
False killer whale	Eastern Tropical Pacific	Unk	Med	Income	Med	Unk	Fisheries interactions, contaminants	Climate change
Fraser's dolphin	Hawaii	Nomadic	Small	Income	Fast	Unk	Fisheries interactions	Climate change
Gray whale	Eastern North Pacific	Migratory	Large	Capital	Slow	Increasing[2]	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise, subsistence hunting	Climate change
Harbor porpoise	Northern California – Southern Oregon	Resident	Small	Income	Fast	Stable	Fisheries interactions, ocean noise (including acoustic deterrent devices or "seal bombs")	Climate change
Harbor porpoise	San Francisco – Russian River	Resident	Small	Income	Fast	Stable	Fisheries interactions, ocean noise (including acoustic deterrent devices or "seal bombs")	Climate change
Harbor porpoise	Monterey Bay	Resident	Small	Income	Fast	Stable	Fisheries interactions, ocean noise (including acoustic deterrent devices or "seal bombs")	Climate change
Harbor porpoise	Morro Bay	Resident	Small	Income	Fast	Increasing	Fisheries interactions, ocean noise (including acoustic deterrent devices or "seal bombs")	Climate change
Harbor seal	California	Resident	Small	Capital	Fast	Stable/ decreasing	Fisheries interactions, power plant entrainment, illegal harassment, vessel strike	Climate change, disease
Humpback whale	Hawaiʻi	Migratory	Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance, ocean noise	Climate change
Killer whale	Eastern North Pacific Offshore	Nomadic	Large	Income	Slow	Stable	Fisheries interactions, vessel strikes, ocean noise	Climate change
Killer whale	Eastern North Pacific Transient/West Coast Transient[7]	Nomadic	Large	Income	Slow	Unknown	Fisheries interactions, vessel strikes, ocean noise	Climate change
Killer whale	Hawaii	Nomadic	Large	Income	Slow	Unk	Fisheries interactions	Climate change
Long-beaked common dolphin	California	Nomadic	Small	Income	Med	Unk; apparent recent increase likely due to	Fisheries interactions, exposure to underwater detonations in coastal waters	Disease (domoic acid toxicity), climate change

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
						distribution shifts north from waters off Mexico		
Longman's beaked whale	Hawaii	Nomadic- resident	Med	Mixed	Med	Unk	Fisheries interactions, ocean noise	Disease, climate change
Melon-headed whale	Hawaiian Islands	Resident-nomadic	Small	Income	Med	Unk	Fisheries interactions, ocean noise	Climate change
Melon-headed whale	Kohala Resident	Resident	Small	Income	Med	Unk	Fisheries interactions, ocean noise	Climate change
Melon-headed whale	Northern Gulf of Mexico	Resident-nomadic	Small	Income	Med	Unk	Fishery interaction, ocean noise, pollution, energy exploration and development, oil spills	Climate change
Mesoplodont beaked whales[3]	California, Oregon, and Washington	Resident - nomadic	Med	Mixed	Med	Unk, possibly increasing	Fisheries interactions, ocean noise	Climate change
Minke whale	California, Oregon, and Washington	Migratory-resident	Med-Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance	Climate change, disease
Minke whale	Hawaii	Migratory	Med-Large	Capital	Slow	Unk	Vessel strikes, fisheries interactions, habitat degradation, pollution, vessel disturbance	Climate change, disease
Northern right whale dolphin	California, Oregon, & Washington	Nomadic	Small	Income	Med	Unk	Fisheries interactions	Climate change
Northern elephant seal	California	Migratory	Small-Med	Capital	Fast	Increasing	Fisheries interactions, illegal harassment, chemical contaminants	–
Northern fur seal	California	Resident	Small	Income	Fast	Increasing	Fisheries interactions	Climate change, El Niño
Northern fur seal	Eastern Pacific	Migratory	Small	Income	Fast	Decreasing	Fisheries interactions, intentional killing/harassment, chemical contaminants	Climate change, disease
Pacific white-sided dolphin	California, Oregon, & Washington	Nomadic	Small	Income	Med	Unk	Entanglement, fisheries interactions	Climate change

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
Pantropical spotted dolphin	Oahu	Resident	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change
Pantropical spotted dolphin	Maui Nui (formerly 4-Islands)	Resident	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change
Pantropical spotted dolphin	Hawaii Island	Resident	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change
Pantropical spotted dolphin	Hawaii Pelagic	Nomadic	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change
Pantropical spotted dolphin	Baja California peninsula, Mexico (not a designated stock)	Nomadic	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change
Pygmy and dwarf sperm whales	California, Oregon, and Washington	Migratory, nomadic, resident	Small-Med	Income	Fast	Unk	Fisheries interactions, marine debris, ocean noise	Climate change
Pygmy and dwarf sperm whales	Hawaii	Migratory, nomadic, resident	Small-Med	Income	Fast	Unk	Fisheries interactions, marine debris, ocean noise	Climate change
Pygmy killer whale	Hawaii	Resident, nomadic	Small	Income	Med	Unk	Fisheries interactions, ocean noise	Climate change
Pygmy killer whale	California – Baja California peninsula, Mexico (not a designated stock)	Unk	Small	Income	Med	Unk	Fisheries interactions, ocean noise	Climate change
Risso's dolphin	California, Oregon, & Washington	Nomadic	Small-Med	Income	Med	Unk	Fisheries interactions	Disease, Climate change
Risso's dolphin	Hawaii	Nomadic	Small-Med	Income	Med	Unk	Fisheries interactions	Climate change
Rough-toothed dolphin	Hawaii	Resident, nomadic	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change

Species	Stock[1]	Movement Ecology	Body Size	Feeding/ Breeding Strategy	Pace of Life	Population Trend	Chronic Anthropogenic Risk Factors[2]	Other Chronic Risk Factors (Non-Noise)
Short-beaked common dolphin	California, Oregon, and Washington	Nomadic	Small	Income	Med	Unk, possibly increasing	Fisheries interactions, exposure to underwater detonations in coastal waters	Climate change
Short-finned pilot whale	California, Oregon, & Washington	Nomadic	Med	Income	Slow	Unk	Fisheries interactions	Climate change
Short-finned pilot whale	Hawaii	Nomadic	Med	Income	Slow	Unk	Fisheries interactions	Climate change
Spinner dolphin	Hawaii Pelagic	Nomadic	Small	Income	Fast	Unk	Fisheries interactions, ocean noise	Disease, climate change
Spinner dolphin	Hawaii Island	Nomadic	Small	Income	Fast	Unk	Swim with the dolphin programs, ocean noise, fisheries interactions	Disease, climate change
Spinner dolphin	Oahu/4-Islands	Nomadic	Small	Income	Fast	Unk	Swim with the dolphin programs, ocean noise, fisheries interactions	Disease, climate change
Spinner dolphin	Kauai and Niihau	Nomadic	Small	Income	Fast	Unk	Swim with the dolphin programs, ocean noise, fisheries interactions	Disease, climate change
Steller sea lion	Eastern U.S.	Resident	Small	Income	Fast	Increasing	Fisheries interactions, harassment/ disturbance at rookeries, commercial aquaculture, illegal intentional killing, chemical contaminants	Climate change
Striped dolphin	California, Oregon, and Washington	Nomadic	Small	Income	Med	Unk	Fisheries interactions	Climate change
Striped dolphin	Hawaii	Nomadic	Small	Income	Med	Unk	Fisheries interactions	Disease, climate change

Notes: Unk = unknown; Med = medium

[1] Stock designations are from Pacific and Alaska Stock Assessment Reports prepared by NMFS (Carretta et al., 2023; Young, 2023).

[2] Fisheries interactions represents entanglement in fishing gear, including derelict fishing gear, and bycatch.

[3] Mesoplodont beaked whales off the U.S. west coast are managed as a single California/Oregon/Washington stock. This stock includes Blainville's, Hubbs', gingko-toothed, Perrin's, lesser (pygmy), and Stejneger's beaked whales.

The costs to marine mammals affected by acoustic and explosive stressors vary based on the type and magnitude of the effect.

- Marine mammals that experience masking may have their ability to communicate with conspecifics reduced, especially at farther ranges. However, larger mysticetes (e.g., blue whale, fin whale, sei whale) communicate at frequencies below those of mid-frequency sonar and even most low-frequency sonars. Other marine mammals that communicate at higher frequencies (e.g., minke whale, dolphins) may be affected by some short-term and intermittent masking. Odontocetes use echolocation to find prey and navigate. The echolocation clicks of odontocetes are above the frequencies of most sonar systems, especially those used during anti-submarine warfare. Therefore, echolocation associated with feeding and navigation in odontocetes is unlikely to be masked by sounds from sonars or other lower frequency broadband sound sources such as explosives. Sounds from mid-frequency sonar could mask killer whale vocalizations, making them more difficult to detect, especially at farther ranges. A single or even a few short periods of masking, if it were to occur, to an individual marine mammal per year are unlikely to have any long-term consequences for that individual.
- Threshold shifts do not necessarily affect all hearing frequencies equally, and typically occur at the exposure frequency or within an octave above the exposure frequency. Recovery from threshold shift begins almost immediately after the noise exposure ceases and can take a few minutes to a few days, depending on the severity of the initial shift, to recover. Most TTS, if it does occur, would likely be minor to moderate (i.e., less than 20 dB of TTS directly after the exposure) and would recover within a matter of minutes to hours. During the period that a marine mammal had hearing loss, social calls from conspecifics could be more difficult to detect or interpret. Killer whales are a primary predator of most other marine mammals. Some hearing loss could make killer whale calls more difficult to detect at farther ranges until hearing recovers. Odontocete echolocation clicks and vocalizations are at frequencies above a few tens of kHz for delphinids, beaked whales, and sperm whales, and above 100 kHz for harbor porpoises and Kogia whales. Echolocation associated with feeding and navigation in odontocetes could be affected by higher-frequency hearing loss but is unlikely to be affected by threshold shift at lower frequencies. It is unclear how or if mysticetes use sound for finding prey or feeding; therefore, it is unknown whether hearing loss would affect a mysticete's ability to locate prey or rate of feeding. A single or even a few TTS in an individual marine mammal per year are unlikely to have any long-term consequences for that individual.
- Auditory injury (AINJ) includes but is not limited to permanent hearing loss. AINJ that did occur would likely be of a small amount (single digit permanent threshold shift) or could cause other physiological changes without any permanent hearing loss (see the *Criteria and Thresholds TR*). In cases where AINJ results in permanent hearing loss, this could reduce an animal's ability to detect sounds that are important for survival (including sounds that facilitate breeding, signal feeding opportunities, and allow avoidance of predators, vessels, and other threats), which could have long-term consequences for individuals. However, permanent loss of some degree of hearing is a normal occurrence as mammals age (see the *Marine Mammal Background Section*). While a small decrease in hearing sensitivity may include some degree of energetic costs, it would be unlikely to impact behaviors, opportunities, or detection capabilities to a degree that would interfere with reproductive success or survival. However, individuals that are already in a compromised state at the time of exposure may be more likely to be impacted as compared to relatively healthy individuals.

- Exposures that result in non-auditory injuries may limit an animal's ability to find food, communicate with other animals, or interpret the surrounding environment. Impairment of these abilities can decrease an individual's chance of survival or impact its ability to successfully reproduce. The death of an animal would eliminate future reproductive potential, which is considered in the analysis of potential long-term consequences to the population.

Assessments of likely long-term consequences to populations of marine mammals are provided by empirical data gathered from areas where military readiness activities routinely occur. Substantial Navy-funded marine mammal survey data, monitoring data, and scientific research have been collected since 2006. These empirical data are beginning to provide insight on the qualitative analysis of the actual (as opposed to model-predicted numerical) impact on marine mammals resulting from training and testing activities based on observations of marine mammals generally in and around range complexes (see the *Background* section).

2.4 Species Impact Assessments

The following sections analyze impacts on each marine mammal stock under the Proposed Action and show model-predicted estimates of take for a maximum year of the proposed action. A star (*) is added to the species header if a species or a distinct population segment is listed as endangered or threatened under the ESA. The analyses rely on information on species presence and behavior in the Study Area presented in the *Marine Mammal Background*. That information is briefly summarized in each species impact analysis. The reader is referred to the *Marine Mammal Background* for additional detail and supporting references.

The methods used to quantify impacts for each substressor are described above in Section 2.2.2 (Quantifying Impact on Marine Mammals from Acoustic and Explosive Stressors). The methods used to assess significance of individual impacts and risks to marine mammal populations are described above in Section 2.3 (Assessing Impacts on Individuals and Populations).

For each stock, a multi-sectioned table quantifies impacts as follows:

Section 1

The first section shows the number of instances of each effect type that could occur due to each substressor (sonar, air gun, pile driving, or explosives) over a maximum year of activity. Impacts are shown by type of activities (Navy training [including U.S. Marine Corps], Coast Guard training, Navy testing activities, or Army training). No in-water explosives or acoustic stressors would result from Air Force activities. While impacts on each stock are assessed holistically, this breakout by types of activities corresponds to the incidental take authorizations requested under the Marine Mammal Protection Act for this Proposed Action.

The number of instances of effect is not the same as the number of individuals that could be affected, as some individuals in a stock could be affected multiple times, whereas others may not be affected at all. The instances of effect are those predicted by the Navy's Acoustic Effects Model and are not further reduced to account for activity-based mitigation that may reduce effects near some sound sources and explosives as described in the *Mitigation* section.

In the modeling, instances of effect are calculated within 24-hour periods of each individually modeled event. Impacts are assigned to the highest order threshold exceeded at the animat, which is a dosimeter in the model that represents an animal of a particular species or stock. Non-auditory injuries are assumed to outrank auditory effects, and auditory effects are assumed to outrank significant behavioral responses. In all instances any auditory impact or injury are assumed to represent a concurrent significant behavioral response. For example, if a significant behavioral response and TTS are predicted for the same animat in a modeled event, the effect is counted as a TTS in the table.

For most activities, total impacts are based on multiplying the average expected impacts at a location by the number of times that activity is expected to occur. This is a reasonable method to estimate impacts for activities that occur every year and multiple times per year. There is one exception to that approach in this analysis: Small Ship Shock Trials (a testing activity using explosives). This activity does not occur every year and has a very small number of total events over seven years. The maximum impacts on any stock in warm or cold season are used.

The summation of instances of effect includes all fractional values caused by averaging multiple modeled iterations of individual events. Impacts are only rounded to whole numbers at the level of substressor and type of activities. Rounding follows standard rounding rules, in which values less than 0.5 round down to the lower whole number, and values equal to or greater than 0.5 round up to the higher whole number.

- A zero value (0) indicates that the sum of impacts is greater than true zero but less than 0.5. These impacts are described in the species analysis as “negligible.”
- A dash (-) indicates that no impacts are predicted (i.e., a “true” zero). This would occur when there is no overlap of an animat in the modeling with a level of acoustic exposure that would result in any possibility of impacts. Non-auditory injury and mortality are only associated with use of explosives; thus, these types of effects are also true zeroes for any other acoustic substressor.
- A one in parentheses (1) indicates that predicted impacts round to zero in a maximum year of activity, but a single impact is predicted over seven years when summing the fractional risks across years. This is explained further below.
- If there are no modeled impacts from a substressor, even though a stressor could occur in a region where a species may be present, this is described as “no effect” in the species analysis and the substressor is not shown on the impact table.
- If there are comparatively few instances of modeled impacts from a substressor, this result will be described in the species analysis as “limited.”
- If there is no geographic overlap between the use of a stressor and the potential presence of a species, this is stated in the analysis.

The summation of impacts across seven years is shown in Section 2.4.5 (Impact Summary Tables). The seven-year sum accounts for any variation in the annual levels of activities. The seven-year sum includes any fractional impact values predicted in any year, which is then rounded following standard rounding rules. That is, the seven-year impacts are not the result of summing the rounded annual impacts.

If a seven-year sum is larger than the annual modeled impacts multiplied by seven, the annual maximum impacts shown in the stock impact tables were increased by dividing the seven-year sum of impacts by seven then rounding up to the nearest integer. For example, this could happen if maximum annual modeled impacts are 1.34 (rounds to 1 annually) and seven-year modeled impacts are 8.60 (rounds to 9), where 9 divided by 7 years (9 ÷ 7 = 1.29) is greater than the rounded annual impact of 1. In this instance, the maximum annual impacts would be adjusted from 1 to 2 based on rounding up 1.29 to 2. In multiple instances, this approach resulted in increasing the maximum annual impacts predicted by the Navy's Acoustic Effects Model.

Section Two

The second section estimates the average number of times an individual in the stock would be affected in a maximum year of activity. The annual impacts per individual is the sum of all instances of effect divided by the population abundance estimate. The annual injurious impacts per individual is only the sum of injuries (auditory, non-auditory, and mortality) divided by the population abundance estimate. The term "injury" in the following species assessments is an inclusive category and may include auditory or non-auditory injuries. When a statement is specific to a type of injury, the injury type (auditory or non-auditory) will be stated.

To estimate repeated impacts across large areas relative to species geographic distributions, comparing the impacts predicted in the Navy's Acoustic Effects Model to abundances predicted using the Navy Marine Species Density Database (NMSDD) models is usually preferable. Per that approach, the ratios of impacts on abundances are based on the same underlying assumptions about a species presence applied in the modeling. The estimates of abundance in NOAA's stock abundance reports, however, may better account for stocks that extend beyond the geographic extent of west coast density models in the NMSDD, such as migratory whales or Alaska stocks. They may also provide a better estimate for stocks that are closely monitored, such as certain ESA-listed species. For each stock, therefore, the population abundance estimate used to assess the potential for repeated takes is the greater of (1) the best population estimate from the stock abundance report prepared by NOAA or (2) the average abundance predicted by the NMSDD.

The annual average abundance values are shown in Table 2.4-1 for stocks with modeled impacts in the Study Area. For the California Study Area, the NMSDD abundances are based on the extent of the west coast density models, which include areas off the Baja California peninsula of Mexico to the south but are truncated to the north and west of the California portion of the Study Area as shown in the *Density TR*. For some species, the NMSDD abundances are based on density models that extend up to the northern extent of the west coast U.S Exclusive Economic Zone, beyond the HCTT Study Area. These are noted in the table. In some instances, even this larger extent does not cover the full range of a species or stock. For the Hawaii Study Area, the NMSDD abundances are based on a buffer around the Hawaiian island chain. Thus, island-associated species are encompassed, but abundances of wider-ranging species may be under-estimated.

NOAA's stock abundance report population estimates and NMSDD abundance estimates can differ substantially because these estimates may be based on different methods and data sources. NOAA's stock abundance reports only consider data from within the prior eight years, whereas the NMSDD considers a longer data history. NOAA's stock abundance reports estimate the number of animals in a population but not spatial densities. NMSDD uses predictive density models to estimate species presence, even where sighting data is limited or lacking altogether. Each density model is limited to the variables and assumptions considered by the original data source provider. These factors and others described in the *Density TR* should be considered when examining the estimated impact numbers in comparison to current population abundance information for any given species or stock.

This analysis does not estimate the distribution of instances of effect across a population (i.e., whether some animals in a population would be affected more times than others). The Navy's Acoustic Effects

Model does not currently model animat movements within, into, and out of the Study Area over a year. Additionally, while knowledge of stock movements and residencies is improving, significant data gaps remain.

Section Three

The third section shows the percent of total impacts that would occur within seasons and general geographic areas. The general geographic areas are Southern California (SOCAL), PMSR, Northern California (NOCAL), Hawaii Range Complex (HRC), and the high seas (transit lanes between the California and Hawaii portions of the Study Area). In the Hawaii Study Area, most activities using sonar and explosives would occur in the Hawaii Range Complex.

Section Four

The fourth section shows which activities are most impactful to a stock. Activities that cause five percent or more of total impacts on a stock are shown.

Section Five (when applicable)

The fifth section shows additional geographical context of impacts. This includes impacts in critical habitats (designated for ESA-listed species) and impacts within Biologically Important Areas. Impacts within these areas may be due to activities within or outside of those areas. Impacts in Biologically Important Areas are only shown for the months that they are in effect. Some Biologically Important Areas consist of a larger “Parent” area and a smaller “Core” or “Child” area within the “Parent.” Impacts shown for “Parent” areas do not exclude the impacts in the “Core” or “Child” areas (i.e., these should not be added to obtain a total count of impacts in the Biologically Important Areas, as some impacts would be double-counted).

The examination of impacts on a *species* within its critical habitat should not be conflated with the analysis of impacts on the critical *habitat* itself or its essential features.

Maps and descriptions of Biologically Important Areas are in the *Marine Mammal Background*. Biologically Important Areas represent areas and times where marine mammal species are known to concentrate for activities related to reproduction, feeding, and migration, as well as the known ranges of small and resident populations. Biologically Important Areas have no legal, statutory, or regulatory power.

Table 2.4-1: Estimated Abundances of Stocks Present in the HCTT Study Area[1]

Species	Stock	SAR[2]	NMSDD[3]
Mysticetes			
Blue whale*	Eastern North Pacific	1,898	3,233[9]
Blue whale*	Central North Pacific	133	170
Bryde’s whale	Hawai'i	791[2]	766
Bryde’s whale	Eastern Tropical Pacific	UNK[6]	69[11]
Fin whale*	Hawai'i	203	226
Fin whale*	California/Oregon/Washington	11,065	12,304[9]
Gray whale	Eastern North Pacific	26,960	10,863[11]
Gray whale*	Western North Pacific	290	110[11]
Humpback whale	Hawai'i	11,278	9,806
Humpback whale*	Mainland Mexico - California/Oregon/Washington	3,477	3,741[9]

Species	Stock	SAR[2]	NMSDD[3]
Humpback whale*	Central America/Southern Mexico - California/Oregon/Washington	1,496	1,603[9]
Minke whale	Hawai'i	438	509
Minke whale	California/Oregon/Washington	915	1,342[9]
Sei whale*	Hawai'i	391	452
Sei whale*	Eastern North Pacific	864[2]	155[11]
Odontocetes			
Baird's beaked whale	California/Oregon/Washington	1,363	871[9]
Blainville's beaked whale	Hawai'i	1,132	1,300
Bottlenose dolphin	California Coastal	453	182
Bottlenose dolphin	California/Oregon/Washington Offshore	3,477	42,395[9,10]
Bottlenose dolphin	Maui Nui (formerly 4-Islands)	64[2]	65
Bottlenose dolphin	Hawai'i Island	136[2]	138
Bottlenose dolphin	Kaua'i/Ni'ihau	112[2]	113
Bottlenose dolphin	O'ahu	112[2]	113
Bottlenose dolphin	Hawai'i Pelagic	24,669[2]	25,120
Goose-beaked (Cuvier's) whale	Hawai'i	4,431	5,116
Goose-beaked (Cuvier's) whale	California/Oregon/Washington	5,454	13,531[9,10]
Dall's porpoise	California/Oregon/Washington	16,498	61,840[9]
Dwarf sperm whale	Hawai'i	UNK[6]	43,246
Dwarf sperm whale	California/Oregon/Washington	UNK[7]	2,462[8,11]
False killer whale	Baja, California Peninsula Mexico[4]	NA	1,990
False killer whale*	Main Hawaiian Islands Insular	138[2]	98
False killer whale	Northwest Hawaiian Islands	477	477
False killer whale	Hawai'i Pelagic	5,528[2]	2,400
Fraser's dolphin	Hawai'i	40,960	47,288
Harbor porpoise	Northern California/Southern Oregon	15,303	1,961[11]
Harbor porpoise	Monterey Bay	3,760	4,530
Harbor porpoise	San Francisco Russian River	7,777	9,974
Harbor porpoise	Morro Bay	4,191	3,885
Killer whale	Hawai'i	161	198
Killer whale*	Southern Resident	73	52
Killer whale	West Coast Transient	349	26[11]
Killer whale	Eastern North Pacific Offshore	300	155[11]
Long-beaked common dolphin	California	83,379	209,100[9]
Longman's beaked whale	Hawai'i	2,550	2,940
Melon-headed whale	Hawaiian Islands	40,647	46,949
Melon-headed whale	Kohala Resident	UNK[6]	447
Mesoplodont beaked whales[5]	California/Oregon/Washington	3,044	7,534[9]
Northern right whale dolphin	California/Oregon/Washington	29,285	68,935[9]
Pacific white-sided dolphin	California/Oregon/Washington	34,999	107,775[9]
Pantropical spotted dolphin	Maui Nui (formerly 4-Islands)	UNK[7]	2,674
Pantropical spotted dolphin	Hawai'i Island	UNK[7]	8,674
Pantropical spotted dolphin	O'ahu	UNK[7]	1,491
Pantropical spotted dolphin	Hawai'i Pelagic	67,313[2]	62,395

Species	Stock	SAR[2]	NMSDD[3]
Pantropical spotted dolphin	Baja, California Peninsula Mexico[4]	NA	70,889
Pygmy killer whale	Hawai'i	10,328	11,928
Pygmy killer whale	California - Baja, California Peninsula Mexico[4]	NA	874
Pygmy sperm whale	Hawai'i	42,083	48,589
Pygmy sperm whale	California/Oregon/Washington	4,111	2,462[8,11]
Risso's dolphin	Hawai'i	6,979[2]	8,649
Risso's dolphin	California/Oregon/Washington	6,336	19,357[9]
Rough-toothed dolphin	Hawai'i	83,915[2]	106,193
Short-beaked common dolphin	California/Oregon/Washington	1,056,308	1,049,117[9]
Short-finned pilot whale	Hawai'i	19,242[2]	23,117
Short-finned pilot whale	California/Oregon/Washington	836	831
Sperm whale*	Hawai'i	5,707	6,062
Sperm whale*	California/Oregon/Washington	2,606[2]	4,549[9]
Spinner dolphin	Hawai'i Island	665	670
Spinner dolphin	Kaua'i Ni'ihau	UNK[6]	606
Spinner dolphin	O'ahu/4-Islands	UNK[6]	355
Spinner dolphin	Hawai'i Pelagic	UNK[6]	6,807
Striped dolphin	Hawai'i Pelagic	64,343[2]	68,909
Striped dolphin	California/Oregon/Washington	29,988	160,551[9]
Pinnipeds			
California sea lion	United States	257,606	199,121[11,12]
Guadalupe fur seal*	Mexico	34,187	48,780[12, 13]
Harbor seal	California	30,968	13,343[12]
Hawaiian monk seal*	Hawai'i	1,564[2]	967[12]
Northern elephant seal	California Breeding	187,386	49,526[11]
Northern fur seal	California	14,050	14,115
Northern fur seal	Eastern Pacific	626,618	89,110[11,12]
Steller sea lion	Eastern	36,308	3,181[11, 12]

SAR: Stock Assessment Report, UNK: Unknown, * = ESA-listed

[1] Values are shown for stocks (or species) with modeled impacts in the Study Area. If a stock is not shown in this table, that stock had no modeled impacts or was not included in the impact modeling because there was no overlap with areas where sonar, air gun, pile driving, or explosive use is anticipated.

[2] Best abundance estimates are from Pacific and Alaska Stock Assessment Reports prepared by NMFS and include the 2023 draft updates (Carretta et al., 2023; Young, 2023).

[3] See the *Density TR* for additional information.

[4] There is no NMFS-designated stock for this population.

[5] Mesoplodont beaked whales off the U.S. west coast are managed as a single California/Oregon/Washington stock. This stock includes Blainville's, Perrin's, lesser (pygmy), Stejneger's, gingko-toothed, and Hubbs' beaked whales.

[6] No SAR population estimate due to lack of recent data (within the last eight years).

[7] No SAR population estimate due to insufficient data.

[8] The NMSDD abundance estimate for Kogia whales is equally split between dwarf and pygmy sperm whales.

[9] Includes the extent of draft NMSDD models off Oregon and Washington.

[10] NMSDD abundances greatly exceed the SAR estimates because the density models predict animals south to areas off the Baja, California Peninsula, Mexico and/or far offshore. For analyzing repeated impacts, animals predicted to be in those locations are assumed to be in the same populations as the NMFS-designated stocks.

[11] A large portion of the range of the stock exceeds the NMSDD extent.

[12] NMSDD in-water densities do not include the portion of pinnipeds that are hauled out.

[13] NMSDD abundance for the Guadalupe fur seal assumes no haul out (see the *Density TR*).

2.4.1 Impacts on Mysticetes

The mysticetes have been split from the previous inclusive LF cetacean auditory group into two auditory groups: the VLF and LF cetaceans. The predicted hearing range of the VLF cetaceans resembles the previous combined auditory group for all mysticetes, whereas the predicted hearing range for the revised LF cetacean group is shifted to slightly higher frequencies.

For sonar exposures, the behavioral response function indicates less sensitivity to behavioral disturbance than predicted in the prior analysis. As described in 2.2.2 (Quantifying Impacts on Hearing), the methods to model avoidance of sonars have been revised to base a species' probability of an avoidance responses on the behavioral response function. Because the probability of behavioral response has decreased for the Mysticete behavioral group while the estimated susceptibility to auditory effects has increased (primarily for the LF hearing group), this analysis predicts more auditory impacts than the prior analysis. In addition, the cut-off conditions for predicting significant behavioral responses have been revised as shown in Section 2.2.3 (Quantifying Behavioral Responses to Sonars). These factors interact in complex ways that the results of this analysis challenging to compare to prior analyses.

Mysticetes would not be exposed to nearshore pile driving in Port Hueneme. Impacts due to non-modeled acoustic stressors are discussed above in Section 2.1.4 (Impacts from Vessel Noise), Section 2.1.5 (Impacts from Aircraft Noise), and Section 2.1.6 (Impacts from Weapons Noise).

2.4.1.1 Blue Whale (*Balaenoptera musculus*)*

Blue whales are in the VLF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the Eastern North Pacific stock and Central North Pacific stock. Blue whales are ESA-listed as endangered throughout their range with no designated DPSs. Model-predicted impacts are presented in Table 2.4-2 and Table 2.4-3. The Eastern North Pacific and Central North Pacific stocks of blue whales are migratory populations that can occur near the coast, over the continental shelf, or in oceanic waters.

The Eastern North Pacific stock of blue whales range from the northern Gulf of Alaska to the eastern tropical Pacific. This stock forages in their hierarchal feeding BIAs in coastal, shelf beak, and deep waters off California in warmer months (June through November) and migrates to areas farther south (Gulf of California) in colder months to breed. In recent years they have been reported to spend more time (averaging over 8 months) on feeding grounds in the Southern California Bight. While this stock can be found along both the California shelf and in deep offshore water, the highest densities of blue whales are predicted along nearshore Southern California where most impacts would occur. Blue whales may be impacted while foraging in the designated BIAs. Most impacts are due to Anti-Submarine Warfare activities in the SOCAL Range Complex. Acoustic and Oceanographic Research using low and mid-frequency sonars also contribute to predicted impacts. Most impacts due to explosives are attributable to Mine Warfare activities in the SOCAL Range Complex. Some impacts are attributable to Small Ship Shock Trials. Both activities have specific activity-based mitigation that may reduce the number of impacts on marine mammals in the area (see the *Mitigation* section for details). The risk of impacts due to air guns is negligible. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance.

The Central North Pacific stock of blue whales migrate from their feeding grounds in the Gulf of Alaska to Hawaii in winter. While they are found in the Hawaii Study Area, they are not sighted frequently or year-round. Most impacts would occur in the Hawaii Range Complex during the cold season (winter to spring) and would be due to Anti-Submarine Warfare activities. Because fewer blue whales are present in this region, there are comparatively fewer impacts on this stock. Impacts due to explosives are limited, and no impacts due to air guns are predicted.

On average, individuals in the Eastern North Pacific stock could be impacted a couple times a year, and individuals in the Central North Pacific stock would be impacted less than once per year. There are no non-auditory injuries predicted for either stock. The average individual risk of auditory injury in both populations is low. The Central North Pacific stock's risk of auditory injury from testing sonar is low (less than one) in any year, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of auditory injury in either stock may be reduced through activity-based mitigation because blue whales are moderately sightable.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Blue whales are large capital breeders with a slow pace of life. They are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Population trends for blue whales are unknown, but possibly increasing in the Eastern North Pacific. Both stocks are endangered. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

A case study examined long-term effects of changing environmental conditions and exposure to military sonar for Eastern North Pacific blue whales on the SOCAL Range Complex based on the description of sonar use in the previous action (2018 HSTT EIS/OEIS). According to the model, only a ten-fold increase in sonar activity combined with a shift in geographical location to overlap with main feeding areas of blue whales would result in a moderate decrease in lifetime reproductive success. Even in such extreme instances, there was still no effect on survival (Pirotta et al., 2022).

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, blue whales. The use of sonars and explosives during training activities may affect, and are likely to adversely affect, blue whales. Activities that involve the use of pile driving are not applicable to blue whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, blue whales. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, blue whales. Pile diving activities are not conducted during testing.

Table 2.4-2: Estimated Effects to the Eastern North Pacific Stock of Blue Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	-	-	-	-
Explosive	Navy Training	65	81	1	-	-
Explosive	Navy Testing	21	25	2	-	-
Explosive	USCG Training	(1)	-	-	-	-
Sonar	Navy Training	646	1,924	16	-	-
Sonar	Navy Testing	696	1,094	8	-	-
Sonar	USCG Training	18	-	-	-	-
Maximum Annual Total		**1,447**	**3,124**	**27**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
3,233	1.42	0.01

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	44%	7%	5%
Cold	43%	1%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	17%
Acoustic and Oceanographic Research (ONR)	Navy Testing	11%
Medium Coordinated Anti-Submarine Warfare	Navy Training	10%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	8%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	7%
At-Sea Sonar Testing	Navy Testing	6%
Composite Training Unit Exercise (Strike Group)	Navy Training	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
F-BIA-C	West Coast (6,7,8,9,10,11)	37	60	1	-	-
F-BIA-P	West Coast (6,7,8,9,10,11)	461	645	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-3: Estimated Effects to the Central North Pacific Stock of Blue Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	-	-	-	-
Sonar	Navy Training	10	56	0	-	-
Sonar	Navy Testing	5	19	(1)	-	-
Sonar	USCG Training	(1)	-	-	-	-
Maximum Annual Total		**17**	**75**	**1**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
170	0.55	0.01

	Percent of Total Effects	
Season	**HRC**	**High Seas**
Warm	29%	1%
Cold	66%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	36%
Acoustic and Oceanographic Research (ONR)	Navy Testing	14%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	9%
Submarine Sonar Maintenance and Systems Checks	Navy Training	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.1.2 Fin Whale (*Balaenoptera physalus*)*

Fin whales are in the VLF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaiian stock. Fin whales are ESA-listed as endangered throughout their range with no designated DPSs. Model-predicted impacts are presented in Table 2.4-4 and Table 2.4-5.

The California, Oregon, and Washington stock of fin whales is a migratory-resident population that travels along the entire U.S. west coast, either in long-range movements or short seasonal trips. They may be present throughout the year in southern and central California, as the Southern California Bight is likely home to a small year-round resident population. However, there are generally higher densities farther offshore in the summer and fall, and closer to shore in winter and spring. Fin whales have the largest hierarchal feeding BIAs spanning the coast of California from June to November, which overlap more with PMSR and SOCAL compared to NOCAL, as the Core BIAs are generally farther offshore in northern California. Impacts would be attributable to various activities in summer and fall (warm season), with most impacts occurring in Southern California year-round. Fin whales may be impacted while foraging in the designated BIAs. Most impacts are due to Anti-Submarine Warfare activities. Acoustic and Oceanographic Research using low and mid-frequency sonars also contribute to predicted impacts. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would occur from a variety of activities, including Ship Shock Trials, Explosive Ordnance Disposal (EOD) Mine Neutralization, and Amphibious Breaching activities, some of which have specific on-site mitigations to reduce the number of impacts on marine mammals in the area (see the *Mitigation* section for details). The risk of impacts due to air guns is negligible.

Fin whales have higher abundances in temperate and polar waters and are not frequently seen in warm, tropical waters. While fin whales are found in the Hawaii Study Area, they are not sighted frequently or year-round. The Hawaii stock of fin whales likely only migrate to the Study Area during fall and winter, which is when they are most likely to experience impacts in the Hawaii Range Complex. Like the California, Oregon, and Washington stock, most impacts on fin whales in Hawaii are due to Anti-Submarine Warfare activities. Because fewer fin whales are present in this region, there are comparatively fewer impacts on this stock. Impacts due to explosives, or injuries due to any stressor, are unlikely.

On average, individuals in the California, Oregon, and Washington stock could be impacted about once a year, and individuals in the Hawaii stock would be impacted less than once per year. The average risk of injury is low, although auditory injuries are predicted, especially for the California, Oregon, and Washington stock. The Hawaii stock's risk of auditory injury from Navy testing sonar is also low (less than one) in any year, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The same is true for the California, Oregon, and Washington stock's risk of non-auditory injury; the impact from Navy training explosives is very low (less than one) in any year, but a non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. The risk of these injuries may be reduced through visual observation mitigation.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Fin whales are large capital breeders with a slow pace of life. They are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Population trends for fin whales are unknown. Both stocks are endangered. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

On average, the limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely. Long-term consequences to both stocks of fin whales are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> fin whales. The use of sonars and explosives during training activities <u>may affect, and are likely to adversely affect,</u> fin whales. Activities that involve the use of pile driving are <u>not applicable</u> to fin whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> fin whales. The use of sonars and explosives during testing activities <u>may affect, and are likely to adversely affect,</u> fin whales. Pile diving activities are not conducted during testing.

Table 2.4-4: Estimated Effects to the California, Oregon, and Washington Stock of Fin Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	0	-	-	-
Explosive	Navy Training	98	114	5	(1)	-
Explosive	Navy Testing	76	69	6	0	-
Explosive	USCG Training	0	0	0	-	-
Sonar	Navy Training	1,727	5,470	22	-	-
Sonar	Navy Testing	1,741	4,144	21	-	-
Sonar	USCG Training	62	-	-	-	-
Maximum Annual Total		**3,704**	**9,797**	**54**	**1**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
12,304	1.10	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	28%	19%	23%
Cold	23%	4%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	21%
Acoustic and Oceanographic Research (ONR)	Navy Testing	17%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
At-Sea Sonar Testing	Navy Testing	10%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	6%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
F-BIA-C	West Coast (6,7,8,9,10,11)	1,405	3,974	19	-	-
F-BIA-P	West Coast (6,7,8,9,10,11)	1,977	5,653	28	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-5: Estimated Effects to the Hawaii Stock of Fin Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	0	0	-	-
Explosive	Navy Testing	(1)	0	-	-	-
Sonar	Navy Training	12	46	0	-	-
Sonar	Navy Testing	5	19	(1)	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**21**	**65**	**1**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
226	0.38	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	24%	1%
Cold	73%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	30%
Acoustic and Oceanographic Research (ONR)	Navy Testing	16%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.1.3 Bryde's Whale (*Balaenoptera brydei/edeni*)

Bryde's whales are in the LF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the Eastern Tropical Pacific and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-6 and Table 2.4-7.

Little is known about the movements of Bryde's whales in the Study Area, but seasonal shifts in their distribution occur toward and away from the equator in winter and summer. Therefore, both populations of Bryde's whales are at least somewhat migratory populations that travel within their tropical and subtropical ranges year-round.

Little is known about the density of the Eastern Tropical Pacific stock other than there appears to be a higher density of Bryde's whales in Southern California compared to the previous analysis. Within the California Study Area, the Eastern Tropical Pacific Stock of Bryde's whales have the highest density in Southern California, which is where they are most likely to experience impacts. Most impacts are due to Intelligence, Surveillance, and Reconnaissance testing activities which include unmanned aerial vehicles, unmanned surface vehicles, unmanned bottom crawlers, and unmanned underwater vehicles that use a variety of active sonar. A small number of auditory injuries are predicted from sonar and explosive activities, but no non-auditory injuries are predicted for this stock.

Bryde's whales are the only baleen whale found in Hawaiian waters year-round, and the only mysticete in Hawaii that does not undergo predictable north-south seasonal migrations. However, Bryde's whales occur mostly in offshore waters of the North Pacific. A population of Bryde's whales congregates near the Main Hawaiian Islands, and while they occur there at a consistently lower density, this population overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would be limited. There would be no impacts due to air guns for either stock.

It is not possible to accurately predict the potential for repeated impacts on individuals in Eastern Tropical Pacific stock. The NMSDD only covers a small portion of the area expected to be inhabited by this population in the eastern Pacific Ocean. Most of this population is present south of the Study Area. Still, the number of predicted impacts is very low, thus the risk of repeated exposures is likely negligible. On average, individuals in the Hawaii stock would experience non-injurious impacts less than once per year. A very small number of auditory injuries could occur to individuals in this stock due to sonar testing and training, although the Hawaii stock's risk of auditory injury from Navy testing sonar is very low (less than one) in any year, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The same is true for the Eastern Tropical Pacific stock's risk of auditory injury; the impact from Navy training sonar and Navy testing explosives is very low (less than one) in any year, but a non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. The risk of injury may be reduced through visual observation mitigation.

Consequences to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Being large capital breeders, Bryde's whales have a slow pace of life and may be less susceptible to impacts from foraging disruption. Even somewhat migratory movement ecology combined with the overall low number of predicted impacts for this stock means the risk of consequences to any individual is low. Long-term consequences to either population is unlikely.

Table 2.4-6: Estimated Effects to the Eastern Tropical Pacific Stock of Bryde's Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	12	39	1	-	-
Explosive	Navy Testing	3	3	(1)	-	-
Sonar	Navy Training	48	80	(1)	-	-
Sonar	Navy Testing	47	89	2	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**111**	**211**	**5**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
69	4.74	0.07

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	39%	2%	2%	1%
Cold	50%	3%	2%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	18%
Mine Countermeasure Technology Research	Navy Testing	11%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	8%
Medium Coordinated Anti-Submarine Warfare	Navy Training	6%
Surface Ship Object Detection	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-7: Estimated Effects to the Hawaii Stock of Bryde's Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	1	(1)	0	-	-
Explosive	Navy Testing	(1)	1	0	-	-
Explosive	Army Training	(1)	(1)	-	-	-
Sonar	Navy Training	41	263	2	-	-
Sonar	Navy Testing	22	75	(1)	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**68**	**341**	**3**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
791	0.52	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	40%	3%
Cold	53%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	30%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Submarine Sonar Maintenance and Systems Checks	Navy Training	12%
Acoustic and Oceanographic Research (ONR)	Navy Testing	9%
Vehicle Testing	Navy Testing	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.1.4 Humpback Whale (*Megaptera novaeangliae*)*

Humpback whales are in the LF cetacean auditory group and the Mysticete behavioral group. Three stocks are in the Study Area – the Central America/Southern Mexico/California, Oregon, and Washington stock (the Central America DPS - endangered), the Mainland Mexico stock/California, Oregon, and Washington stock (part of the Mexico DPS - threatened), and the Hawaii stock (the Hawaii DPS – not ESA-listed).

2.4.1.4.1 ESA-listed Humpback Whales (Central America DPS and Mexico DPS)

Model-predicted impacts are presented in Table 2.4-8 and Table 2.4-9.

Humpback whales in the California Study Area are most abundant in shelf and slope waters which are areas of high productivity. While they are often sighted near shore, they also frequently travel through deep offshore waters during migration. The Central America/Southern Mexico/California, Oregon, and Washington stock (Central America DPS) migrates from breeding grounds in Central America to their northern feeding grounds, parts of which are in the California Study Area. Similarly, the Mainland Mexico stock/California, Oregon, and Washington stock (part of the Mexico DPS) of humpback whales migrates from breeding grounds in Mexico to their northern feeding grounds, parts of which are in the California Study Area. Unlike the Central American stock, humpback whales of the Mainland Mexico stock also migrate to the northeast (e.g., Alaska, Andalusian Islands, Russia).

The Central America/Southern Mexico/California, Oregon, and Washington stock (Central America DPS) of humpback whales may be present in the Study Area year-round, but specifically utilize hierarchal feeding ground BIAs March through November. This stock of humpback whales migrates through California with peak abundance December through June ("cold season"), when humpbacks are most likely to be impacted by sonar training and testing activities in Southern California. Some impacts on humpback whales would occur in critical habitat, and they may be impacted while foraging in the BIAs off the coast of California. Most impacts are due to Anti-Submarine Warfare activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would be limited and the risk of impacts due to air guns is negligible.

The Mainland Mexico stock/California, Oregon, and Washington stock (part of the Mexico DPS) of humpback whales shares a similar migration pattern with the Central America/Southern Mexico/California, Oregon, and Washington stock, and has the highest abundance in California Study Area during the cold season, when humpbacks are most likely to be impacted by sonar training and testing activities in Southern California. Some impacts on humpback whales would occur in critical habitat, and they may be impacted while foraging in the hierarchal BIAs off the coast of California. Most impacts are due to Anti-Submarine Warfare activities, including on humpback whale critical habitat. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would be limited and the risk of impacts due to air guns is negligible.

On average, individuals in the Central America/Southern Mexico/California, Oregon, and Washington stock (Central America DPS) or the Mainland Mexico stock/California, Oregon, and Washington stock (part of the Mexico DPS) of humpback whales could be impacted about once a year. These impacts are most likely to occur in the cold season when humpbacks would be migrating and feeding along California. The average risk of injury is low, although it is likely that some auditory injuries could occur, particularly from sonar activities during Navy training events. The risk of a single non-auditory injury from testing explosives is low (less than one) in any year for the Mainland Mexico stock/California, Oregon, and Washington stock, but a non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). This auditory injury is shown in the maximum year of impacts per the summation and rounding approach discussed above. The risk of injury may be reduced through activity-based mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Humpback whales are large capital breeders with a slow pace of life. Although some impacts are likely to occur when humpbacks are engaged in feeding behavior, they are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Although the Central America/Southern Mexico/California, Oregon, and Washington stock population may be increasing, they are also endangered. The Mainland Mexico stock/California, Oregon, and Washington stock of humpback whales is depleted and threatened. Both stocks of humpback whales that migrate along California face the added risk of pot and trap fishery entanglements, which are the most common source of injury to humpback whales in the area. Humpback whales’ slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory or non-auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, humpback whales in the Central American DPS. The use of sonars and explosives during training activities may affect, and are likely to adversely affect, humpback whales in the Central American DPS. Activities that involve the use of pile driving are not applicable to humpback whales in the Central American DPS because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, humpback whales in the Central American DPS. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, humpback whales in the Central American DPS. Pile diving activities are not conducted during testing.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, humpback whales in the Mexico DPS. The use of sonars and explosives during training activities may affect, and are likely to adversely affect, humpback whales in the Mexico DPS. Activities that involve the use of pile driving are not applicable to humpback whales in the Mexico DPS because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, humpback whales in the Mexico DPS. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, humpback whales in the Mexico DPS. Pile diving activities are not conducted during testing.

Critical Habitat

The critical habitats designated by NMFS for humpback whales encompass biological features essential to conservation of the species (81 *Federal Register* 4838). One essential feature was identified for humpback whale critical habitat, defined as prey species, primarily euphausiids and small pelagic schooling fishes, of sufficient quality, abundance, and accessibility within humpback whale feeding areas to support feeding and population growth. The northern units (Unit 15, 16, and 17) overlap the NOCAL Range Complex, which are key areas essential for humpback whale foraging and migration. The only biological feature designated by NMFS for the Central America and Mexico DPS of humpback whales is the presence of euphausiids (krill) and small fish such as pacific sardines, northern anchovy, and pacific herring, particularly in the San Francisco-Monterey Bay Area within the northern units. The southern units (Units 17 and 18) overlap PMSR and the northern portion of the SOCAL Range Complex, which are also BIAs for foraging. Maps of these critical habitats are in the *Marine Mammal Background*.

While use of sonar and noise produced by vessels, aircraft, and weapons firing would overlap critical habitat, they would not affect the essential prey feature in the critical habitat that is essential for the reproduction, rest and refuge, health, continued survival, conservation, and recovery of this species. Non-impulsive sound sources, such as sonars, have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007) and would only be expected to result in behavioral reactions or potential masking in fishes and marine invertebrates. Most sonar sources proposed for use during training and testing activities overlapping or adjacent to critical habitat in the Study Area would not fall within the frequency range of marine invertebrate or fish hearing, thereby presenting no plausible route of effect on humpback whale prey species. The few sources used within invertebrate and fish hearing range would be limited and typically transient, as shown in Appendix A (Activity Descriptions) and examined in the *Impacts on Fishes from Acoustic and Explosive Stressors* section. Pile driving would only occur in Point Hueneme, thus would not overlap critical habitat for humpback whales. Limited use of air guns could occur in critical habitat. Air guns may affect prey species very close to the source, although the single air guns used during testing are less powerful than those used in seismic surveys. Any impacts would be minimal, localized, and would not overall reduce aggregations of prey species.

Explosive stressors that occur in the NOCAL Range Complex, PMSR, and SOCAL Range Complex would overlap Central America DPS and Mexico DPS designated critical habitat. Use of explosives may kill or injure prey species that are present near these explosives. As shown in the Section 4.4.4 (Range to Effects for Explosives), the median range to fish mortality due to explosives categorized as E12 (> 675–1,000 lb. NEW), the largest explosive proposed in the humpback whale critical habitat, is up to 760 m. However, the largest explosive bins are very limited in number and would not occur in the NOCAL Range Complex, which includes the humpback whale feeding ground near the San Francisco-Monterey Bay Area, nor in PMSR. The ranges for smaller explosive bins are correspondingly shorter. Specifically, the median range to fish mortality due to an E3 (> 0.5–2.5 lb. NEW) explosive, the largest explosive proposed in the NOCAL Range Complex, is 64 m. In the NOCAL Range Complex, any explosive activities will be at least 12 NM from the closest point of land, which will avoid or reduce impacts on fish in nearshore habitat areas. Although any impacts on prey fishes and invertebrates would be limited due to the limited number and size of explosives proposed for use in the NOCAL Range Complex, a small number of prey items that could be present in the nearby and overlapping critical habitat could no longer be available; however, injuries would not be anticipated to remove prey items from the population. Fish prey items that occur within the PMSR and SOCAL Range Complex portions of designated critical habitat and within the estimated ranges to mortality may be killed. Those that are killed within any portion of the proposed critical habitat would no longer be available as prey items. Other potential impacts from exposure to explosions include injury, TTS, physiological stress and behavioral reactions. The ranges to these lower level impacts would be considerably larger than the range to mortality. However, these impacts would not be anticipated to remove individuals (prey) from the population, nor would any non-mortal temporary or isolated impacts on prey items be expected to reduce the quality of prey in terms of nutritional content.

Sonars and vessel, aircraft, and weapons noise during training activities would have <u>no effect</u> on designated critical habitats for humpback whales in the Central American DPS. The use of explosives during training activities <u>may affect, but is not likely to adversely affect,</u> designated critical habitats for humpback whales in the Central American DPS. Activities that involve the use of pile driving are <u>not applicable</u> to humpback whale critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.

Sonars and vessel, aircraft, and weapons noise during testing activities would have <u>no effect</u> on designated critical habitats for humpback whales in the Central American DPS. The use of air guns and explosives during testing activities <u>may affect, but is not likely to adversely affect,</u> designated critical habitats for humpback whales in the Central American DPS. Pile diving activities are not conducted during testing.

Sonars and vessel, aircraft, and weapons noise during training activities would have <u>no effect</u> on designated critical habitats for humpback whales in the Mexico DPS. The use of explosives during *training activities may affect, but is not likely to adversely affect, designated critical habitats for humpback whales in the Mexico DPS. Activities that involve the use of pile driving are not applicable to humpback whale critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.*

Sonars and vessel, aircraft, and weapons noise during testing activities would have no effect on designated critical habitats for humpback whales in the Mexico DPS. The use of air guns and explosives during testing activities may affect, but is not likely to adversely affect, designated critical habitats for humpback whales in the Mexico DPS. Pile diving activities are not conducted during testing.

Table 2.4-8: Estimated Effects to the Central America/Southern Mexico DPS within the California, Oregon, and Washington Stock of Humpback Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	-	-	-	-
Explosive	Navy Training	18	27	(1)	-	-
Explosive	Navy Testing	13	11	1	-	-
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	166	831	13	-	-
Sonar	Navy Testing	343	472	4	-	-
Sonar	USCG Training	7	-	-	-	-
Maximum Annual Total		**547**	**1,341**	**19**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,603	1.19	0.01

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	5%	6%	17%
Cold	51%	14%	6%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	20%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	12%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	11%
Acoustic and Oceanographic Research (ONR)	Navy Testing	10%
At-Sea Sonar Testing	Navy Testing	7%
Anti-Submarine Warfare Torpedo Exercise – Ship	Navy Training	6%
Unmanned Underwater Vehicle Testing	Navy Testing	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	CA Central Coast (All)	25	111	1	-	-
Critical Habitat	CA North Coast (All)	0	1	-	-	-
Critical Habitat	Channel Islands Area (All)	30	141	2	-	-
Critical Habitat	San Francisco Monterey Bay Area (All)	28	295	4	-	-
F-BIA-C	West Coast (3,4,5,6,7,8,9,10,11)	7	28	1	-	-
F-BIA-P	West Coast (3,4,5,6,7,8,9,10,11)	40	214	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-9: Estimated Effects to the Mainland Mexico DPS within the California, Oregon, and Washington Stock of Humpback Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	0	-	-	-
Explosive	Navy Training	35	85	3	-	-
Explosive	Navy Testing	31	29	1	(1)	-
Explosive	USCG Training	(1)	0	-	-	-
Sonar	Navy Training	375	1,906	31	-	-
Sonar	Navy Testing	818	1,155	8	-	-
Sonar	USCG Training	14	-	-	-	-
Maximum Annual Total		**1,274**	**3,175**	**43**	**1**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
3,741	1.20	0.01

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	6%	6%	17%	0%
Cold	52%	12%	6%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	19%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	12%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	11%
Acoustic and Oceanographic Research (ONR)	Navy Testing	10%
At-Sea Sonar Testing	Navy Testing	7%
Anti-Submarine Warfare Torpedo Exercise – Ship	Navy Training	6%
Undersea Warfare Testing	Navy Testing	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	CA Central Coast (All)	54	222	4	-	-
Critical Habitat	CA North Coast (All)	0	3	0	-	-
Critical Habitat	Channel Islands Area (All)	71	307	4	-	-
Critical Habitat	San Francisco Monterey Bay Area (All)	64	680	10	-	-
F-BIA-C	West Coast (3,4,5,6,7,8,9,10,11)	17	72	1	-	-
F-BIA-P	West Coast (3,4,5,6,7,8,9,10,11)	94	495	8	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.1.4.2 Non-ESA-listed Humpback Whales (Hawaii DPS)

Model-predicted impacts are presented in Table 2.4-10.

The Hawaiian stock of humpback whales has particularly strong site fidelity on hierarchal reproductive BIAs in the nearshore waters surrounding the main Hawaiian Islands during peak breeding season (December through May), although whales may be present through June. Since humpback whales are only seasonally in the Hawaii Study Area, most impacts would occur during the cold season, and are very unlikely to occur during the warm season or on the high seas. Humpback whales may be impacted while engaging in reproductive behaviors in the designated BIAs. Most impacts are due to Anti-Submarine Warfare activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would be limited and impacts from air guns would be unlikely.

On average, individuals in the Hawaii stock would be impacted less than once per year. These impacts are most likely to occur in the cold season when humpbacks would be seasonally present in the area and engaged in breeding behavior. The average risk of injury is low, although it is likely that some auditory injuries could occur, particularly from sonar activities during Navy training events. The risk of injury may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Humpback whales are large capital breeders with a slow pace of life. Although some impacts are likely to occur when humpbacks are engaged in feeding behavior, they are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. The Hawaii stock of humpback whales is not endangered, and their population trend is unknown. Humpback whales' slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Table 2.4-10: Estimated Effects to the Hawaii Stock of Humpback Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	48	58	7	-	-
Explosive	Navy Testing	40	32	2	-	-
Explosive	Army Training	3	1	-	-	-
Sonar	Navy Training	780	1,358	11	-	-
Sonar	Navy Testing	348	358	4	-	-
Sonar	USCG Training	7	-	-	-	-
Maximum Annual Total		**1,227**	**1,807**	**24**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
11,278	0.27	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	1%	0%
Cold	97%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	13%
Anti-Submarine Warfare Torpedo Exercise – Ship	Navy Training	11%
Submarine Navigation	Navy Training	10%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	7%
Surface Ship Object Detection	Navy Training	6%
Anti-Submarine Warfare Torpedo Exercise – Submarine	Navy Training	6%
Acoustic and Oceanographic Research (ONR)	Navy Testing	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
R-BIA-C	Main Hawaiian Islands (1,2,3,4,5,12)	237	200	6	-	-
R-BIA-P	Main Hawaiian Islands (1,2,3,4,5,12)	838	545	10	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.1.5 Minke Whale (*Balaenoptera acutorostrata*)

Minke whales are in the LF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-11 and Table 2.4-12.

The California, Oregon, and Washington stock generally congregates in nearshore waters over the continental shelf off California and has low variability in annual distribution patterns. Their year-round abundance in Southern California overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Auditory impacts are also attributable to low and mid-frequency sonars during other testing activities, including those with higher duty cycles. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. The number of impacts due to explosives are limited and the risk of impacts due to air guns is negligible.

The Hawaii stock generally congregates in Hawaiian water in the colder months (fall to spring) and migrates to more productive areas in winter. Their seasonally high densities in Hawaii in the colder months overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. The number of impacts due to explosives are negligible.

On average, individuals in the California, Oregon, and Washington stock could be impacted a couple times a year, and individuals in the Hawaii stock would be impacted less than once per year. The average risk of injury is low, although auditory injuries are predicted. The risk of injury may be reduced through visual observation mitigation, although minke whales have a relatively low sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Although they are the smallest mysticete, minke whales are large capital breeders with a slow pace of life. Migratory minke whales in Hawaii are likely to sustain fewer impacts during the warm season when their local abundance is lower, whereas impacts off the U.S. west coast would likely occur for more resident minke populations year-round. Although some impacts are likely to occur when minke whales are engaged in feeding behavior, they are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Population trends for minke whales are unknown. Both stocks of minke whales are not endangered. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Table 2.4-11: Estimated Effects to the California, Oregon, and Washington Stock of Minke Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	-	-	-	-
Explosive	Navy Training	29	81	9	-	-
Explosive	Navy Testing	9	10	1	-	0
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	334	1,242	15	-	-
Sonar	Navy Testing	563	718	7	-	-
Sonar	USCG Training	7	-	-	-	-
Maximum Annual Total		**942**	**2,051**	**32**	**-**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,342	2.25	0.02

Season	Percent of Total Effects: SOCAL	PMSR	NOCAL
Warm	36%	7%	7%
Cold	39%	6%	5%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	14%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	13%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	12%
Acoustic and Oceanographic Research (ONR)	Navy Testing	8%
At-Sea Sonar Testing	Navy Testing	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-12: Estimated Effects to the Hawaii Stock of Minke Whales over a Maximum Year of Proposed Activity

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	1	(1)	-	-	-
Explosive	Navy Testing	1	(1)	0	-	-
Explosive	Army Training	(1)	-	-	-	-
Sonar	Navy Training	27	200	2	-	-
Sonar	Navy Testing	12	50	(1)	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**44**	**252**	**3**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
509	0.59	0.01

Season	Percent of Total Effects: HRC	High Seas
Warm	29%	2%
Cold	67%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	37%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	13%
Acoustic and Oceanographic Research (ONR)	Navy Testing	9%
Submarine Sonar Maintenance and Systems Checks	Navy Training	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.1.6 Gray Whale (*Eschrichtius robustus*)*

Gray whales are in the LF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the Eastern North Pacific stock (not ESA-listed) and the Western North Pacific stock (the Western North Pacific DPS – endangered).

2.4.1.6.1 ESA-listed Gray Whales (Western North Pacific DPS)

Model-predicted impacts are presented in Table 2.4-13.

Gray whales are migratory marine mammals and could be present in the California Study Area during their northward and southward migrations from winter to spring, within 10 km of the coast. However, the Western North Pacific stock is very rare in the Study Area since it is critically endangered and abundance is very low. Impacts would be more likely in the cold season in Southern California as they migrate north. Their higher seasonal abundance in this area overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on the Western North Pacific stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would be extremely limited.

On average, individuals in the Western North Pacific stock would be impacted less than once per year. These impacts are most likely to occur in the cold season when gray whales would be only seasonally in the area during migration. The average risk of injury is very low, although it is possible that a couple auditory injuries could occur. Additionally, the risk of an auditory injury from training sonar is less than one in any year, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Therefore, the risk of auditory injury from any source is unlikely (less than two) for the Western North Pacific stock. The risk of injury for this stock of gray whales may be reduced through visual observation mitigation.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Gray whales are large capital breeders with a slow pace of life. They are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. However, the Western North Pacific stock is endangered and shows no apparent signs of recovery. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> gray whales in the Western North Pacific DPS. The use of sonars and explosives during training activities <u>may affect, and are likely to adversely affect,</u> gray whales in the Western North Pacific DPS. Noise produced by pile driving would have <u>no effect</u> on gray whales in the Western North Pacific DPS. Air gun activities are not conducted during training.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> gray whales in the Western North Pacific DPS. The use of sonars and explosives during testing activities <u>may affect, and are likely to</u>

<u>adversely affect,</u> gray whales in the Western North Pacific DPS. Noise produced by air guns would have <u>no effect</u> on gray whales in the Western North Pacific DPS. Pile diving activities are not conducted during testing.

Table 2.4-13: Estimated Effects to the Western North Pacific DPS of Gray Whales over a Maximum Year of Proposed Activity

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	(1)	0	-	-
Explosive	Navy Testing	2	(1)	0	-	-
Sonar	Navy Training	18	28	(1)	-	-
Sonar	Navy Testing	50	67	1	-	-
Sonar	USCG Training	(1)	-	-	-	-
Maximum Annual Total		**72**	**97**	**2**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
290	0.59	0.01

Season	Percent of Total Effects	
	SOCAL	PMSR
Warm	0%	0%
Cold	97%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
At-Sea Sonar Testing	Navy Testing	21%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	19%
Anti-Submarine Warfare Torpedo Exercise – Ship	Navy Training	19%
Undersea Warfare Testing	Navy Testing	15%
Unmanned Underwater Vehicle Testing	Navy Testing	10%
Anti-Submarine Warfare Tracking Exercise – Ship	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.1.6.2 Non-ESA-listed Gray Whales (Eastern North Pacific DPS)

Model-predicted impacts are presented in Table 2.4-14.

The Eastern North Pacific stock of gray whales may be present in the California Study Area in higher densities than the Western North Pacific stock of gray whales since this stock is not endangered and has a greater abundance. Impacts on the Eastern North Pacific stock of gray whales would be more likely in the cold season as they migrate north of the Bering Sea to forage in the summer. Their higher seasonal abundance in the hierarchical migratory BIAs and non- hierarchical reproductive BIA, especially in Southern California, overlaps areas where Anti-Submarine Warfare activities would occur. Gray whales may be impacted while migrating and engaging in reproductive behaviors in the designated BIAs. Since multiple BIAs overlap geographically and sometimes seasonally, BIAs' impacts in Table 2.4-14 are not mutually exclusive. For example, the gray whale Northbound Phase A and Northbound Phase B BIAs are geographically the same but are distinct in demographic and season. The Phase B migration BIA is used by mother-calf pairs in a more limited seasonal window (March–May) compared to the Phase A migration BIA used by adults and juveniles (January–May). Most sonar impacts on the Western North Pacific stocks are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts from explosives would occur from a variety of activities, primarily Mine Warfare. No impacts are predicted for air guns.

On average, individuals in the Eastern North Pacific stock would be impacted less than once per year. These impacts are most likely to occur in the cold season when gray whales would be only seasonally in the area during migration. The average risk of injury is very low, although it is likely that some auditory injuries could occur, particularly from sonar during Anti-Submarine Warfare activities or explosives during Mine Warfare activities. The risk of injury for this stock of gray whales may be reduced through visual observation mitigation.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Gray whales are large capital breeders with a slow pace of life. They are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Although the Eastern North Pacific stock of gray whales is not endangered, there was an unusual mortality event for this stock of gray whales within their range from 2019 to 2024, in which hundreds of whales died and decreased the population by 40%. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Table 2.4-14: Estimated Effects to the Eastern North Pacific DPS of Gray Whales over a Maximum Year of Proposed Activity

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	-	-	-	-
Explosive	Navy Training	234	391	33	0	-
Explosive	Navy Testing	123	56	5	0	-
Explosive	USCG Training	0	(1)	-	-	-
Sonar	Navy Training	1,903	2,390	65	-	-
Sonar	Navy Testing	4,876	6,722	64	-	-
Sonar	USCG Training	15	-	-	-	-
Maximum Annual Total		**7,151**	**9,560**	**167**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
26,960	0.63	0.01

	Percent of Total Effects	
Season	**SOCAL**	**PMSR**
Warm	1%	0%
Cold	97%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
At-Sea Sonar Testing	Navy Testing	20%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	19%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	16%
Undersea Warfare Testing	Navy Testing	14%
Unmanned Underwater Vehicle Testing	Navy Testing	8%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
M-BIA-C	Northbound Phase A (1,2,3,4,5)	6,969	9,357	157	-	-
M-BIA-C	Northbound Phase B (3,4,5)	5,672	7,844	132	-	-
M-BIA-C	Southbound (11,12,1,2)	1,338	1,556	29	-	-
M-BIA-P	West Coast to Gulf of Alaska (11,12,1,2,3,4,5,6)	7,023	9,417	163	-	-
R-BIA	Northbound Phase B (3,4,5)	5,672	7,844	132	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.

Source	Category	BEH	TTS	AINJ	INJ	MORT

Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.1.7 Sei Whale (*Balaenoptera borealis*)*

Sei whales are in the LF cetacean auditory group and the Mysticete behavioral group. Two stocks are in the Study Area – the Eastern North Pacific stock and the Hawaii stock. Sei whales are listed as endangered throughout their range with no designated DPSs. Model-predicted impacts are presented in Table 2.4-15 and Table 2.4-16.

Sei whales generally have higher abundances in the cold and deep water of the open ocean. The Eastern North Pacific stock of sei whales has some seasonal migrations that are less extensive compared to other mysticetes. This stock of sei whales is most frequently found in the offshore waters of California, and likely occur in the Transit Corridor portion of the Study Area. Their year-round higher densities in deep waters near Southern California overlap areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. The number of impacts due to explosives are limited and there are no predicted impacts due to air guns.

The Hawaii stock of sei whales is migratory, traveling from their cold subpolar latitudes to Hawaii in the winter. While they are not frequently detected in Hawaii, they are more likely to be on the Hawaii Range Complex in the cold season which overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts due to explosives are unlikely and there are no predicted impacts due to air guns.

On average, individuals from either stock would be impacted less than once per year. The average risk of injury is negligible, although a few auditory injuries are predicted. The risk of a single auditory injury from testing explosives or testing sonar is low (less than one) in any year for the Eastern North Pacific stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Likewise, the risk of a single auditory injury from testing or training sonar is low (less than one) in any year for the Hawaii stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. These auditory injuries are shown in the maximum year of impacts per the summation and rounding approach discussed above. Therefore, the risk of auditory injury from any source is unlikely for either the Eastern North Pacific and Hawaii stocks (less than three and two, respectively). The risk of injury may be reduced through activity-based mitigation because sei whales are moderately sightable.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Sei whales are large capital breeders with a slow pace of life. Migratory sei whales in Hawaii are likely to sustain fewer impacts during the warm season when their local abundance is lower, whereas impacts off the U.S. west coast, and particularly in Southern California are more likely to occur year-round. Sei whales are expected to be resilient to short-term foraging disruptions due to their reliance on built-up energy reserves. Population trends for sei whales are unknown. Both stocks are endangered. Their slow pace of life means that long-term impacts on breeding adults could have a longer-term effect on population growth rates.

Limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to the stock are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> sei whales. The use of sonars and explosives during training activities <u>may affect, and are likely to adversely affect,</u> sei whales. Activities that involve the use of pile driving are <u>not applicable</u> to sei whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> sei whales. The use of sonars and explosives during testing activities <u>may affect, and are likely to adversely affect,</u> sei whales. Noise produced by air guns would have <u>no effect</u> on sei whales. Pile diving activities are not conducted during testing.

Table 2.4-15: Estimated Effects to the Eastern North Pacific Stock of Sei Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	5	1	0	-	-
Explosive	Navy Testing	2	2	(1)	-	-
Sonar	Navy Training	38	151	1	-	-
Sonar	Navy Testing	37	65	(1)	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**83**	**219**	**3**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
864	0.35	0.00

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	30%	5%	5%	2%
Cold	42%	8%	7%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	17%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Acoustic and Oceanographic Research (ONR)	Navy Testing	12%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	9%
Composite Training Unit Exercise (Strike Group)	Navy Training	7%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-16: Estimated Effects to the Hawaii Stock of Sei Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	1	(1)	0	-	-
Explosive	Navy Testing	0	0	-	-	-
Explosive	USCG Training	-	0	-	-	-
Sonar	Navy Training	25	173	(1)	-	-
Sonar	Navy Testing	11	41	(1)	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**38**	**215**	**2**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
452	0.56	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	30%	1%
Cold	65%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	37%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	18%
Acoustic and Oceanographic Research (ONR)	Navy Testing	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2 Impacts on Odontocetes

The odontocetes are divided into the HF and VHF cetacean hearing groups. In addition to proposing more hours of hull-mounted sonars in this Proposed Action, the updated HF cetacean criteria reflect greater susceptibility to auditory effects at low and mid-frequencies than previously analyzed. Consequently, the predicted auditory effects due to sources under 10 kHz, including but not limited to MF1 hull-mounted sonar and other anti-submarine warfare sonars, are substantially higher for this auditory group than in prior analyses of the same activities. Thus, for activities with sonars, some modeled exposures that would previously have been categorized as significant behavioral responses may now instead be counted as auditory effects (TTS and AINJ). Similarly, the updated HF cetacean criteria reflect greater susceptibility to auditory effects at low and mid-frequencies in impulsive sounds. For VHF cetaceans, susceptibility to auditory effects has not changed substantially since the prior analysis.

The methods to model sonar avoidance have also been revised to base a species' probability of an avoidance responses on the behavioral response functions as described in Section 2.2.2 (Quantifying Impacts on Hearing). The combined behavioral response function for Sensitive Species replaces the two prior distinct behavioral response functions for beaked whales and porpoises. Due to their greater susceptibility to disturbance, HF and VHF cetaceans in the Sensitive behavioral group are predicted to avoid many auditory injuries. All other odontocetes remain in the Odontocete behavioral group, including VHF cetaceans that are not behaviorally sensitive (e.g., Dall's porpoise and Kogia whales). Because the probability of behavioral response has decreased for the Odontocete behavioral group while the estimated susceptibility to auditory effects has increased for the HF hearing group (susceptibility to auditory effects has not notably changed for the VHF cetaceans), this analysis predicts more auditory impacts than the prior analysis for these species. The cut-off conditions for predicting significant behavioral responses have also been revised for both the Sensitive Species and Odontocete behavioral groups as shown in Section 2.2.3 (Quantifying Behavioral Responses to Sonars). These factors interact in complex ways that make comparing the results of this analysis to prior analyses challenging.

Impacts due to non-modeled acoustic stressors are discussed above in Section 2.1.4 (Impacts from Vessel Noise), Section 2.1.5 (Impacts from Aircraft Noise), and Section 2.1.6 (Impacts from Weapons Noise).

2.4.2.1 Sperm Whale (*Physeter macrocephalus*)*

Sperm whales are in the HF cetacean auditory group and the Odontocete behavioral group. Two stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Sperm whales are listed as endangered throughout their range with no designated DPSs. Model-predicted impacts are presented in Table 2.4-17 and Table 2.4-18.

Sperm whales generally have higher abundances in deep water and areas of high productivity. The California, Oregon, and Washington stock of sperm whales are somewhat migratory. While some individuals leaving warm waters in summer to travel to their arctic feeding grounds and returning south in the fall and winter, an annual density estimate was applied to the California portion of the Study Area since seasonally specific values are not currently available. A portion of this stock found year-round in California waters over the continental shelf break, over the continental slope, and into deeper waters. Most impacts on this stock are due to antisubmarine warfare activities in the Southern California portion of the study area, which could overlap areas with higher sperm whale densities in deep waters. The number of impacts due to explosives are limited and there are no predicted impacts due to air guns.

The Hawaii stock of sperm whales is more residential and are one of the more abundant large whales found in that region. Sperm whales occur in Hawaiian waters year-round, overlapping areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are auditory effects because mysticetes are relatively less sensitive to disturbance. Impacts due to explosives and air guns would be limited.

On average, individuals from either stock would be impacted less than once per year. The annual average individual risk of injury is negligible, although a few auditory injuries are predicted. The risk of any auditory injury due to training explosives, testing explosives, and training sonar is low (less than one) in any year for the California, Oregon, and Washington stock, but auditory injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Likewise, the risk of a single auditory injury from training explosives is low (less than one) in any year for the Hawaii stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. The risk of injury may be reduced through visual observation mitigation.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As large odontocetes with a slow pace of life, sperm whales are likely more resilient to missed foraging opportunities due to acoustic disturbance than smaller odontocetes. Still, sperm whales are income breeders and may be more susceptible to impacts due to lost foraging opportunities during reproduction, especially if they occur during lactation (Farmer et al., 2018). Sperm whales are somewhat migratory, but their movement ecology is demographically dependent. Nursery groups of females, claves and non-adult males are more residential, staying near warm equatorial breeding grounds throughout the year. Groups of adult males are more migratory, traveling from warm waters in the summer to feeding grounds as far north as the

Arctic. Migratory whales may be less susceptible to repeated impacts than residential whales near range complexes. Because of their longer generation times, this population would require more time to recover if significantly impacted. In addition, both stocks of sperm whales are endangered and depleted with unknown population trends, although it is possible that sperm whales in California, Oregon, and Washington have a stable population.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Long-term consequences to the stock are unlikely.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, sperm whales. The use of sonars and explosives during training activities may affect, and are likely to adversely affect, sperm whales. Activities that involve the use of pile driving are not applicable to sperm whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, sperm whales. The use of sonars, explosives, and air guns during testing activities may affect, and are likely to adversely affect, sperm whales. Pile diving activities are not conducted during testing.

Table 2.4-17: Estimated Effects to the California, Oregon, and Washington Stock of Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	2	4	(1)	-	-
Explosive	Navy Testing	2	1	(1)	-	-
Explosive	USCG Training	0	-	-	-	-
Sonar	Navy Training	2,133	758	(1)	-	-
Sonar	Navy Testing	834	129	-	-	-
Sonar	USCG Training	28	-	-	-	-
Maximum Annual Total		**2,999**	**892**	**3**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
4,549	0.86	0.00

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	32%	6%	5%	2%
Cold	38%	9%	5%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	20%
Medium Coordinated Anti-Submarine Warfare	Navy Training	18%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	7%
Composite Training Unit Exercise (Strike Group)	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-18: Estimated Effects to the Hawaii Stock of Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	2	1	(1)	-	-
Explosive	Navy Testing	0	(1)	-	-	-
Sonar	Navy Training	939	354	0	-	-
Sonar	Navy Testing	288	56	0	-	-
Sonar	USCG Training	7	-	-	-	-
Maximum Annual Total		**1,237**	**412**	**1**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
6,062	0.27	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	43%	2%
Cold	51%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	29%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	10%
Submarine Sonar Maintenance and Systems Checks	Navy Training	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.2 Dwarf and Pygmy Sperm Whale (*Kogia sima* and *Kogia breviceps*)

Dwarf and pygmy sperm whales are analyzed together, as these species are difficult to distinguish during wildlife surveys and as a result are frequently classified together as Kogia species. Kogia species are in the VHF cetacean auditory group and the Odontocete behavioral group. Two stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-19 and Table 2.4-20 for dwarf sperm whales, and Table 2.4-21 and Table 2.4-22 for pygmy sperm whales.

Kogia density values for the Study Area are presented differently for Hawaii and California. In Hawaii there is enough data on dwarf and pygmy sperm whales to provide density estimates for each species separately, but fewer live sightings have occurred off the U.S. west coast, so density values are provided for Kogia as a genus. Additionally, density data are insufficient to identify any seasonal patterns in the distribution of Kogia, so these estimates are considered to represent year-round densities. Kogia's higher densities in deep waters along California, especially Southern California, overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on the California, Oregon, and Washington stocks of dwarf and pygmy sperm whales are due to these activities. The number of impacts due to explosives and air guns in this portion of the Study Area are limited. There would be no impacts due to pile driving because there is no geographic overlap of this stressor with species occurrence.

There are hierarchical small and resident population BIAs for dwarf sperm whales on the west coast of the island of Hawaii. Dwarf sperm whales may be minimally impacted while in the nearshore designated BIAs. Both stocks of Kogia are present year-round in Hawaii with higher densities on the Hawaii Range Complex, which overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on the Hawaii stocks of dwarf and pygmy sperm whales are due to these activities. Dwarf sperm whales appear to prefer tropical waters more than pygmy sperm whales, which are rarely reported, and may contribute to the higher impacts on dwarf sperm whales in Hawaii. Impacts from explosives would occur from a variety of activities, including Amphibious Breaching Operations, Missile and Gunnery Exercises, and Mine Countermeasure activities that have specific on-site mitigations that may reduce the number of impacts on marine mammals in the area (see the *Mitigation* section for details). The number of impacts due to air guns are limited.

On average, individuals in the Hawaii stocks could be impacted about once per year, and individuals in the California, Oregon, and Washington stocks would be impacted a couple times per year. The average risk of injury is low, although a few auditory and non-auditory injuries are predicted. The risk of any air gun auditory injury is negligible (less than one) in any year for the Hawaii stock of dwarf sperm whales, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Likewise, the risk of a non-auditory injury from explosives is also incredibly low (less than one) in any year for either stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. These auditory and non-auditory injuries are shown in the maximum year of impacts per the summation and rounding approach discussed above. The risk of injury may be reduced through visual observation mitigation, although Kogia are cryptic and have low sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small-medium odontocetes that are income breeders with a fast pace of life, dwarf and pygmy sperm whales are likely less resilient to missed foraging opportunities, especially during lactation. Little is known about the movement ecology of these stocks, other than a small resident population of dwarf sperm whales off the west coast of the Island of Hawaii, which will likely increase the risk of repeated impacts on individual dwarf sperm whales in that portion of the Study Area. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations would be quick to recover.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory or non-auditory injury may experience minor energetic costs. Most predicted impacts are temporary auditory effects that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to these stocks are unlikely.

Table 2.4-19: Estimated Effects to the California, Oregon, and Washington Stock of Dwarf Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	1	-	-	-
Explosive	Navy Training	12	35	13	-	-
Explosive	Navy Testing	20	33	17	-	0
Explosive	USCG Training	(1)	(1)	(1)	-	-
Sonar	Navy Training	936	3,346	37	-	-
Sonar	Navy Testing	519	709	26	-	-
Sonar	USCG Training	16	34	-	-	-
Maximum Annual Total		**1,505**	**4,159**	**94**	**-**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
2,462	2.34	0.04

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	32%	4%	6%	1%
Cold	43%	6%	7%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	24%
Medium Coordinated Anti-Submarine Warfare	Navy Training	17%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	8%
Composite Training Unit Exercise (Strike Group)	Navy Training	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-20: Estimated Effects to the Hawaii Stock of Dwarf Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	8	5	(1)	-	-
Explosive	Navy Training	272	407	171	(1)	0
Explosive	Navy Testing	86	107	27	0	0
Explosive	USCG Training	1	1	(1)	-	-
Explosive	Army Training	51	46	12	-	-
Sonar	Navy Training	8,114	27,505	329	-	-
Sonar	Navy Testing	2,189	6,048	371	-	-
Sonar	USCG Training	159	225	2	-	-
Maximum Annual Total		**10,880**	**34,344**	**914**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
43,246	1.07	0.02

Season	Percent of Total Effects	
	HRC	High Seas
Warm	43%	3%
Cold	50%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	32%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Submarine Sonar Maintenance and Systems Checks	Navy Training	7%
Vehicle Testing	Navy Testing	7%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Hawaii Island (All)	0	3	0	-	-
S-BIA-P	Hawaii Island (All)	1	14	2	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-21: Estimated Effects to the California, Oregon, and Washington Stock of Pygmy Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	1	-	-	-
Explosive	Navy Training	19	41	23	0	-
Explosive	Navy Testing	22	33	18	-	-
Explosive	USCG Training	(1)	(1)	0	-	-
Sonar	Navy Training	964	3,216	43	-	-
Sonar	Navy Testing	525	743	23	-	-
Sonar	USCG Training	17	31	-	-	-
Maximum Annual Total		**1,549**	**4,066**	**107**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
4,111	1.39	0.03

	Percent of Total Effects			
Season	**SOCAL**	**PMSR**	**NOCAL**	**High Seas**
Warm	30%	4%	6%	1%
Cold	44%	6%	7%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	22%
Medium Coordinated Anti-Submarine Warfare	Navy Training	18%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	8%
Composite Training Unit Exercise (Strike Group)	Navy Training	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-22: Estimated Effects to the Hawaii Stock of Pygmy Sperm Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	6	6	1	-	-
Explosive	Navy Training	259	414	167	(1)	0
Explosive	Navy Testing	97	114	28	0	-
Explosive	USCG Training	1	(1)	(1)	-	-
Explosive	Army Training	57	51	15	-	-
Sonar	Navy Training	8,131	27,918	350	-	-
Sonar	Navy Testing	2,243	6,137	373	-	-
Sonar	USCG Training	160	192	-	-	-
Maximum Annual Total		**10,954**	**34,833**	**935**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
48,589	0.96	0.02

Season	Percent of Total Effects	
	HRC	High Seas
Warm	43%	3%
Cold	50%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	32%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Submarine Sonar Maintenance and Systems Checks	Navy Training	7%
Vehicle Testing	Navy Testing	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.3 Baird's Beaked Whale (*Berardius bairdii)*

Baird's beaked whales are in the HF cetacean auditory group and the Sensitive behavioral group. The California, Oregon, and Washington stock is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-23.

Baird's beaked whales range from Mexico to Alaska and are typically found in deep waters over the continental slope, near oceanic seamounts, and areas with submarine escarpments, although they may be seen close to shore where deep water approaches the coast. While the California, Oregon, and Washington stock is primarily located along the continental slope during the warm season and are presumed to be farther offshore during part of the cold season, the lack of quantitative seasonal information on this species resulted in these density estimates being applied year-round. Overall, this stock seems to have a higher density in the cold waters of northern California, however there is still a concentration of Baird's beaked whales in deep waters offshore southern California which overlaps areas where a relatively high concentration of Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Most impacts are behavioral effects because beaked whales are in the Sensitive behavioral group and are relatively more avoidant to noise sources. The number of impacts due to explosives is extremely limited and there would be no impacts due to air guns.

On average, individuals from the California, Oregon, and Washington stock would be impacted several times per year. Most of these impacts would be behavioral responses. There is no predicted risk of auditory or non-auditory injury to this stock.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. While beaked whales are mixed breeders (i.e., behaviorally income breeders), they demonstrate capital breeding strategies during gestation and lactation (Keen et al., 2021), so they may be more vulnerable to prolonged loss of foraging opportunities during gestation. However, as large odontocetes with a slow pace of life, Baird's beaked whales are more resilient to missed foraging opportunities due to acoustic disturbance compared to other beaked whale species. Because Baird's beaked whales have a nomadic-resident movement ecology, the risk of repeated impacts on individuals is likely similar within the population as animals move throughout their range. However, since this species has longer generation times, this population would require more time to recover if significantly impacted.

Several instances of behavioral disturbance over a year are unlikely to have any long-term consequences for individuals. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock of Baird's beaked whales are unlikely. Most predicted impacts are behavioral responses in an open ocean basin that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to these stocks are unlikely.

Table 2.4-23: Estimated Effects to the California, Oregon, and Washington Stock of Baird's Beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	-	1	-	-	-
Explosive	Navy Testing	1	(1)	0	-	-
Sonar	Navy Training	7,234	55	-	-	-
Sonar	Navy Testing	2,823	5	-	-	-
Sonar	USCG Training	54	-	-	-	-
Maximum Annual Total		**10,112**	**62**	**0**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,363	7.46	0.00

Season	Percent of Total Effects: SOCAL	PMSR	NOCAL
Warm	27%	8%	11%
Cold	31%	9%	13%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	22%
Medium Coordinated Anti-Submarine Warfare	Navy Training	16%
Acoustic and Oceanographic Research (ONR)	Navy Testing	15%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	8%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.4 Blainville's Beaked Whale (*Mesoplodon densirostris*)

Blainville's beaked whales are in the HF cetacean auditory group and the Sensitive behavioral group. Two Blainville's beaked whale stocks are in the Study Area – the combined California, Oregon, and Washington Mesoplodont stock and the Hawaii stock. Model-predicted impacts on the Hawaii stock are presented in Table 2.4-24. Impacts on the California, Oregon, and Washington combined Mesoplodont stock are discussed in Section 2.4.2.7 (Mesoplodont Beaked Whales).

There are hierarchical small and resident population BIAs designated for Blainville's beaked whales in the waters around the island of Hawaii to Oahu, with a concentration of use off the west coast and North Kohala portion of the Island of Hawaii. Blainville's beaked whale behavior may be impacted within these BIAs, particularly the larger parent BIA. The Hawaii stock of Blainville's beaked whales is residential and their year-round higher densities on the Hawaii Range Complex overlap areas where Sonar Maintenance and Anti-Submarine Warfare activities would occur. Most sonar impacts on the Hawaii stocks of Blainville's beaked whales are due to these activities. The number of impacts due to explosives is extremely limited, and there would be no impacts due to air guns.

On average, individuals in the Hawaii stock of Blainville's beaked whales could be impacted several times per year, primarily due to behavioral responses.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes with a medium pace of life, Blainville's beaked whales are likely moderately resilient to missed foraging opportunities due to acoustic disturbance. While beaked whales are mixed breeders (i.e., behaviorally income breeders), they demonstrate capital breeding strategies during gestation and lactation (Keen et al., 2021), so they may be more vulnerable to prolonged loss of foraging opportunities during gestation. Because Blainville's beaked whales have a nomadic-resident movement ecology, the risk of repeated impacts on individuals is likely similar within the population as animals move throughout their range. However, since this species has longer generation times, this population would require more time to recover if significantly impacted.

Limited instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Based on the above analysis, long-term consequences for the Hawaii stock of Blainville's beaked whales are unlikely.

Table 2.4-24: Estimated Effects to the Hawaii Stock of Blainville's Beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	-	-	-	-
Explosive	Navy Testing	0	-	-	-	-
Explosive	Army Training	-	(1)	-	-	-
Sonar	Navy Training	5,780	31	-	-	-
Sonar	Navy Testing	1,702	2	-	-	-
Sonar	USCG Training	25	-	-	-	-
Maximum Annual Total		**7,508**	**34**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,300	5.80	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	42%	3%
Cold	52%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Sonar Maintenance and Systems Checks	Navy Training	21%
Medium Coordinated Anti-Submarine Warfare	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Submarine	Navy Training	10%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Oahu-Maui Nui-Hawaii Island - Hawaii Island (All)	6	-	-	-	-
S-BIA-P	Oahu-Maui Nui-Hawaii Island (All)	778	1	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.5 Goose-beaked Whale (*Ziphius cavirostris*)

Goose-beaked whales (also known as Cuvier's beaked whales) are in the HF cetacean auditory group and the Sensitive behavioral group. Two goose-beaked whale stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-25 and Table 2.4-26.

This species is the more commonly encountered beaked whale species off the U.S. west coast. The California, Oregon, and Washington stock of goose-beaked whales generally congregate in deep offshore waters of California, with repeated sightings of the same individuals off San Clemente Island in Southern California, indicating some level of site fidelity. Density estimates from the goose-beaked whale model were applied year-round to the portion of the Navy's acoustic modeling study area. Their year-round higher densities in deep waters off Southern California overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. There would be no impacts due to air guns.

The Hawaii stock of goose-beaked whales is relatively common off the Hawaiian Islands of Lanai, Maui, Hawaii, Niihau, and Kauai, which provide strong evidence for both insular and offshore populations of goose-beaked whales in waters of the Hawaiian Islands EEZ. Hierarchical small and resident population BIAs were redefined for a year-round resident population of goose-beaked whales in Hawaiian waters, particularly between the 2,000- and 3,500-meter isobaths off the leeward side of the Island of Hawaii, where they spend most of their time. Goose-beaked whale behavior may be impacted within these BIAs, particularly the larger parent BIA. Their year-round higher densities in Hawaiian waters overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts due to air guns are extremely limited.

On average, individuals in the California, Oregon, and Washington stock could be impacted over a dozen times per year, primarily due to behavioral responses. Beaked whales are a behaviorally sensitive species, and their high density in Southern California and the offshore portions of central and northern California overlaps areas where Anti-Submarine Warfare activities typically occur. The revised cut-off conditions for significant behavioral responses result in predicting significant responses farther than observed in studies of beaked whale responses to sonar (see Section 2.3.3 [Behavioral Responses by Distance and Sound Pressure Level]). On average, individuals in the Hawaii stock would be impacted several times per year, primarily due to behavioral responses. The average risk of injury for either stock is negligible, although a few auditory injuries are predicted. The risk of auditory injury from explosive training is low (less than one) in any year for either stock of goose-beaked whales, but a couple auditory injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). These auditory injuries are shown in the maximum year of impacts per the summation and rounding approach discussed above. The risk of injury may be reduced through visual observation mitigation, although beaked whales have low sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes with a medium pace of life, goose-beaked whales are likely moderately resilient to missed foraging opportunities due to acoustic disturbance. While beaked whales are mixed breeders (i.e., behaviorally income breeders), they demonstrate capital breeding strategies during gestation and lactation (Keen et al., 2021), so they may be more vulnerable to prolonged loss of foraging opportunities during gestation. Since about 40 percent of the goose-beaked whales that were assessed in photo-identification studies in the SOCAL Range Complex have been seen in one or more prior years, with re-sightings up to seven years apart, there is likely a resident population on the range (Falcone & Schorr, 2014; Falcone et al., 2009). Because goose-beaked whales have a nomadic-resident movement ecology, the risk of repeated impacts on individuals is likely similar within the population as animals move throughout their range. The individuals that are more residential to areas on the SOCAL Range Complex or Hawaii Range Complex may be at higher risk for repeated exposure and long-term consequences from repeated displacement (Hin et al., 2023). Since this species has longer generation times, this population would require more time to recover if significantly impacted.

Several instances of behavioral disturbance over a year are unlikely to have any long-term consequences for most individuals, although individuals who suffer an auditory injury or repeated displacement may experience minor energetic costs. Most predicted impacts are behavioral responses in an open ocean basin that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to these stocks are unlikely.

Table 2.4-25: Estimated Effects to the California, Oregon, and Washington Stock of Goose-beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	6	13	(1)	-	-
Explosive	Navy Testing	8	3	1	0	-
Explosive	USCG Training	0	-	-	-	-
Sonar	Navy Training	110,330	504	-	-	-
Sonar	Navy Testing	55,207	92	-	-	-
Sonar	USCG Training	653	-	-	-	-
Maximum Annual Total		**166,204**	**612**	**2**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
13,531	12.33	0.00

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	37%	4%	2%	3%
Cold	45%	4%	2%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	25%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	9%
Acoustic and Oceanographic Research (ONR)	Navy Testing	7%
Medium Coordinated Anti-Submarine Warfare	Navy Training	6%
Vehicle Testing	Navy Testing	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-26: Estimated Effects to the Hawaii Stock of Goose-beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	2	1	0	-	-
Explosive	Navy Testing	1	(1)	0	-	-
Explosive	Army Training	(1)	(1)	0	-	-
Sonar	Navy Training	23,137	118	-	-	-
Sonar	Navy Testing	6,945	8	-	-	-
Sonar	USCG Training	143	-	-	-	-
Maximum Annual Total		**30,230**	**129**	**0**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
5,116	5.93	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	42%	3%
Cold	52%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Sonar Maintenance and Systems Checks	Navy Training	21%
Medium Coordinated Anti-Submarine Warfare	Navy Training	12%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Submarine	Navy Training	9%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%
Acoustic and Oceanographic Research (ONR)	Navy Testing	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Hawaii Island (All)	77	0	-	-	-
S-BIA-P	Hawaii Island (All)	710	2	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.6 Longman's Beaked Whale (*Indopacetus pacificus)*

Longman's beaked whales are in the HF cetacean auditory group and the Sensitive behavioral group. The Hawaii stock is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-27.

While the full extent of the Longman's beaked whale distribution is not fully understood, there have been many sightings in tropical waters throughout the Pacific and Indian Oceans in waters over deep bathymetric slopes from 200 to 2,000 m. The Hawaii stock of Longman's beaked whales generally congregate in warm deep waters. The lack of quantitative seasonal information on this species resulted in these density estimates being applied year-round. In addition, the Hawaii stock of Longman's beaked whales has a uniform density value which was applied throughout the Hawaii Range Complex portion of the Study Area and the western portion of the transit corridor. Their higher densities in the Hawaii Range Complex overlap areas where Sonar Maintenance and Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts due to explosives would be limited, and there would be no impacts due to air guns.

On average, individuals in the Hawaii stock could be impacted several times per year, primarily due to behavioral responses. Beaked whales are a behaviorally sensitive species, and their high density in Hawaii overlaps areas where Anti-Submarine Warfare activities typically occur. The revised cut-off conditions for significant behavioral responses result in predicting significant responses farther than observed in studies of beaked whale responses to sonar (see Section 2.3.3 [Behavioral Responses by Distance and Sound Pressure Level]). The average risk of injury is negligible, although one auditory injury is predicted. The risk of injury may be reduced through visual observation mitigation, although beaked whales have low sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes with a medium pace of life, Longman's beaked whales are likely moderately resilient to missed foraging opportunities due to acoustic disturbance. While beaked whales are mixed breeders (i.e., behaviorally income breeders), they demonstrate capital breeding strategies during gestation and lactation (Keen et al., 2021), so they may be more vulnerable to prolonged loss of foraging opportunities during gestation. Because Longman's beaked whales have a nomadic-resident movement ecology, the risk of repeated impacts on individuals is likely similar within the population as animals move throughout their range.

Several instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Most predicted impacts are behavioral responses in an open ocean basin that are unlikely to contribute to any long-term impacts on individuals. Long-term consequences to these stocks are unlikely.

Table 2.4-27: Estimated Effects to the Hawaii Stock of Longman's Beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	(1)	1	-	-
Explosive	Navy Testing	0	0	-	-	-
Explosive	Army Training	(1)	(1)	-	-	-
Sonar	Navy Training	13,966	83	-	-	-
Sonar	Navy Testing	4,106	12	-	-	-
Sonar	USCG Training	145	-	-	-	-
Maximum Annual Total		**18,219**	**97**	**1**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
2,940	6.23	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	41%	3%
Cold	53%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Sonar Maintenance and Systems Checks	Navy Training	22%
Medium Coordinated Anti-Submarine Warfare	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Submarine	Navy Training	9%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.7 Mesoplodont Beaked Whales

Mesoplodont beaked whales are in the HF cetacean auditory group and the Sensitive behavioral group. Due to the difficulty in distinguishing species during visual surveys, Mesoplodont beaked whales off the U.S. west coast are managed as a single California/Oregon/Washington stock. This stock includes

Blainville's (*M. densirostris*), Perrin's (*M. perrini*), lesser (pygmy) (*M. peruvianus*), Stejneger's (*M. stejnegeri*), gingko-toothed (*M. gingkodens*), and Hubbs' (*M. carlhubbsi*) beaked whales. Model-predicted impacts on this stock are presented in Table 2.4-28.

Most mesoplodont beaked whale species have a wide distribution and are not residential to any location within the California portion of the Study Area. Even Blainville's beaked whales, which are one of the most widely distributed deep-diving beaked whale species, are not common in the California portion of the Study Area. Stejneger's beaked whales are much more common in Alaskan waters compared to the California portion of the Study Area. Pygmy beaked whale's distribution extends from central California to Chile, so their abundance is likely much higher outside the U.S. Exclusive Economic Zone. A possible exception may be Perrin's beaked whale. Although little is known about Perrin's beaked whale distribution, they have stranded several times in the California portion of the Study Area, so it is possible that their population may be more localized.

Mesoplodont beaked whales are typically found in offshore oceanic waters greater than 200 meters deep along the California coast and are only occasionally reported in waters over the continental shelf. A year-round density is applied due to the lack of quantitative seasonal information. Their higher densities in deep waters off Southern California overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Most impacts are behavioral effects because beaked whales are in the Sensitive behavioral group and are likely to avoid noise sources. The number of impacts due to explosives is limited, and the risk of impacts due to air guns is negligible.

The abundance predicted for this population using the NMSDD includes the west coast extent of this stock as well as areas off the Baja California peninsula of Mexico. Most of these beaked whale species have wide distributions and are not residential to any location within the California Study Area (except possibly Perrin's beaked whales). Given that, individual Mesoplodont beaked whales from the California, Oregon, and Washington stock are estimated to be impacted over a dozen times per year on average. Most of these impacts would be behavioral responses. The risk of auditory injury from explosive testing or training is very low (less than one) in any year, but a couple auditory injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation, although beaked whales have low sightability. There is no predicted risk of non-auditory injury or mortality in any year.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes with a medium pace of life, Mesoplodont beaked whales are likely moderately resilient to missed foraging opportunities due to acoustic disturbance. While beaked whales are mixed breeders (i.e., behaviorally income breeders), they demonstrate capital breeding strategies during gestation and lactation (Keen et al., 2021), so they may be more vulnerable to prolonged loss of foraging opportunities during gestation. Because Mesoplodont beaked whales have a nomadic movement ecology, the risk of repeated impacts on individuals is likely similar within the population as animals move throughout their range.

Several instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury may experience minor energetic costs. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock of Mesoplodont beaked whales are unlikely.

Table 2.4-28: Estimated Effects to the California/Oregon/Washington Stock of Mesoplodont Beaked Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	0	-	-	-	-
Explosive	Navy Training	2	5	(1)	-	-
Explosive	Navy Testing	6	3	1	0	0
Explosive	USCG Training	(1)	-	0	-	-
Sonar	Navy Training	64,298	350	0	-	-
Sonar	Navy Testing	27,697	62	-	-	-
Sonar	USCG Training	415	-	-	-	-
Maximum Annual Total		**92,419**	**420**	**2**	**0**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
7,534	12.32	0.00

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	34%	6%	2%	3%
Cold	42%	6%	2%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	25%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	10%
Acoustic and Oceanographic Research (ONR)	Navy Testing	7%
Medium Coordinated Anti-Submarine Warfare	Navy Training	7%
Vehicle Testing	Navy Testing	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.8 Killer Whale (*Orcinus orca*)*

Killer whales are in the HF cetacean auditory group and the Odontocete behavioral group. Four killer whale stocks are in the Study Area – the Southern Resident stock (the Southern Resident DPS – endangered), the Eastern North Pacific Offshore stock, the Eastern North Pacific West Coast Transient stock, and the Hawaii stock.

2.4.2.8.1 ESA-listed Killer Whales (Southern Resident DPS)

There are no predicted impacts on the endangered Southern Resident stock of killer whales. This stock is largely residential to the Salish Sea, north of the California Study Area. While a sub-set of Southern Resident killer whales (K and L pods) may travel into the NOCAL Range Complex from January to May, where they could be exposed to noise in the designated small and resident population BIA from a limited number of military readiness activities, they typically do not travel south of Monterey, California. Since they do not have any modeled impacts in the HCTT Study Area, the impact of acoustic stressors on this stock will not be analyzed further.

The use of sonars, explosives, and activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> Southern Resident killer whales. Activities that involve the use of pile driving are <u>not applicable</u> to Southern Resident killer whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

The use of sonars, explosives, air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities <u>*may affect, but are not likely to adversely affect,*</u> *Southern Resident killer whales. Pile diving activities are not conducted during testing.*

<u>*Critical Habitat*</u>

The critical habitat designated by NMFS for Southern Resident killer whales (86 *Federal Register* 41668) off California is largely coastal, with waters 6 m to 200 m deep. It is made up of three continuous sections of Californian coast: the Northern CA Coast Area, the North Central CA Coast Area, and the Monterey Bay Area. The critical habitat extends into the NOCAL Range Complex and as far south as Monterey, California. A map of this critical habitat is in *Biological Resources Supplemental Information*. Sound or energy from sonars, vessels, aircrafts, weapons, air guns, and explosives during military readiness activities could overlap this designated critical habitat. The essential features for the conservation of the Southern Resident DPS designated critical habitat include (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging.

While use of sonar and noise produced by vessels, aircraft, and weapons firing would overlap critical habitat, they would not affect the essential prey feature in the critical habitat that is essential for the reproduction, rest and refuge, health, continued survival, conservation, and recovery of this species. Non-impulsive sound sources, such as sonars, have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007) and would only be expected to result in behavioral reactions or potential masking in fishes. Most sonar sources proposed for use during training and testing activities overlapping or adjacent to critical habitat in the Study Area would not fall within the frequency range of fish hearing, thereby presenting no plausible route of effect on Southern Resident killer whale prey species. The few sources used within fish hearing range would be limited and typically transient, as shown in Appendix A (Activity Descriptions) and examined in the *Impacts on Fishes from Acoustic and Explosive Stressors* section. Pile driving would only occur in Point Hueneme, thus would not overlap critical habitat for Southern Resident killer whale in northern California. Limited use of air guns could occur in critical habitat. Air guns may affect prey species very close to the source, although the single air guns used during testing are less powerful than those used in seismic surveys. Any impacts would be minimal, localized, and would not overall reduce aggregations of prey species.

Explosives would not be used in Southern Resident critical habitat. The limited use of explosives in the NOCAL Range Complex adjacent to critical habitat may kill or injure nearby prey species, removing a small number of prey that could have been available in the critical habitat. As described in the Fishes section, the median range to fish mortality due to a bin E3 (> 0.5–2.5 lb. NEW) explosive, the largest explosive proposed in the NOCAL Range Complex, is 64 m. A small number of mortalities would not appreciably diminish the conservation value of the habitat as a whole.

Sonars and vessel, aircraft, and weapons noise during training activities would have <u>*no effect*</u> *on designated critical habitats in California for the Southern Resident DPS of killer whales. The use of explosives during training activities* <u>*may affect, but is not likely to adversely affect*</u>*, designated critical habitats in California for the Southern Resident DPS of killer whales. Activities that involve the use of pile driving are* <u>*not applicable*</u> *to Southern Resident killer whale critical habitats because there is no* *geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.*

Sonars and vessel, aircraft, and weapons noise during testing activities would have no effect on designated critical habitats in California for the Southern Resident DPS of killer whales. The use of air guns and explosives during testing activities may affect, but is not likely to adversely affect, designated critical habitats in California for the Southern Resident DPS of killer whales. Pile diving activities are not conducted during testing.

2.4.2.8.2 Non-ESA-listed Killer Whales

Model-predicted impacts are presented in Table 2.4-29, Table 2.4-30, and Table 2.4-31.

Killer whales can occur in coastal zones or deep ocean basins but are most numerous in coastal water at higher latitudes. The Eastern North Pacific Offshore (Offshore) and Eastern North Pacific West Coast Transient (Transient) stocks occur along the west coast of North America, from the Alaskan coast, along the outer coasts of Washington, Oregon, and California.

The Eastern North Pacific Offshore stock of killer whales generally congregate in northern offshore waters but can be found in Southern California as well. The Offshore stock has a larger southern range compared to the Transient stock of killer whales, especially farther offshore. The absence of seasonally specific data on this stock resulted in killer whale density estimates being applied year-round. Within the California Study Area, the Eastern North Pacific Offshore stock of killer whales is most likely to be impacted in Southern California, as more activities overlap this stock presence in this region. Most impacts are due to Mine Warfare activities and related research and training that may employ lower source levels, but for longer activity durations and at frequencies where HF cetaceans are susceptible to auditory impacts. Anti-Submarine Warfare activities also contribute to impacts for the Eastern North Pacific Offshore stock. A small number of auditory injuries are predicted from explosive activities, but no non-auditory injuries are predicted for this stock. There would be no impacts due to air guns.

The Eastern North Pacific West Coast Transient stock generally congregates in cold waters and higher latitudes. The absence of seasonally specific data on this stock resulted in killer whale density estimates being applied year-round. Therefore, the Transient stock of killer whales in the California portion of the Study Area have the highest year-round density in northern California, which is where they are most likely to experience impacts. Most impacts are due to Anti-Submarine Warfare activities. No injuries are predicted, and there would be no impacts due to explosives or air guns for this stock.

Killer whales are not frequently seen in Hawaiian waters. The Hawaii stock of killer whales is typically only seen during winter, suggesting those sighted in Hawaii are seasonal migrants to Hawaii. However, insufficient seasonal information on this species resulted in these density estimates being applied year-round and is likely to artificially increase the impact on this Hawaiian stock. Killer whales have higher density around the Hawaiian Islands compared to the high seas, which is where they are most likely to experience impacts. Most impacts are due to Anti-Submarine Warfare activities. No injuries are predicted, and there would be no impacts due to explosives or air guns for this stock. Fewer impacts are predicted for this stock in Hawaii because fewer killer whales are found in this warm tropical region.

The potential for repeated impacts on individual killer whale in the Study Area is low. On average, Individuals in the Offshore stock would be impacted a few times per year, and individuals in the Transient or Hawaii stocks would be impacted less than once per year. The average individual risk of injurious impacts is negligible, although a few auditory injuries are predicted for the Offshore stock.

However, the risk of an auditory injury from explosive testing is low (less than one) in any year, but a couple auditory injuries from explosive testing is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). These auditory injuries are shown in the maximum year of impacts per the summation and rounding approach discussed above. Therefore, the risk of auditory injury is less likely, even for the Offshore stock of killer whales. There is no risk of injury for the Transient or Hawaii stocks of killer whales. The risk of auditory injury for the Offshore stock may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Killer whales are large, income-breeding odontocetes with a slow pace of life, suggesting they are more resilient to missed foraging opportunities due to acoustic disturbance, except during lactation. All four stocks of killer whales move within their range year-round. Because most killer whale stocks in the Study Area are nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Although the Southern Resident killer whale population is critically endangered and decreasing, the Proposed Action will have much less impact on this stock of killer whales since they are largely residential to waters outside of the HCTT Study Area. The other three stocks of killer whales in the Study Area are not endangered and either have stable (Eastern North Pacific offshore stock) or unknown population trends. Overall, killer whales would be resilient to missed foraging opportunities but would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who suffer an auditory injury would experience energetic costs. Based on the above analysis, long-term consequences for the Eastern North Offshore, Eastern North Pacific West Coast Transient, and Hawaii stocks of killer whales are unlikely.

Table 2.4-29: Estimated Effects to the Eastern North Pacific Offshore Stock of Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	6	7	3	-	-
Explosive	Navy Testing	2	1	(1)	0	-
Sonar	Navy Training	422	110	0	-	-
Sonar	Navy Testing	399	75	0	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**830**	**193**	**4**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
300	3.42	0.01

	Percent of Total Effects			
Season	SOCAL	PMSR	NOCAL	High Seas
Warm	34%	2%	2%	1%
Cold	54%	4%	2%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	26%
Surface Ship Object Detection	Navy Training	21%
Mine Countermeasure Technology Research	Navy Testing	11%
Medium Coordinated Anti-Submarine Warfare	Navy Training	6%
Unmanned Underwater Vehicle Training - Certification and Development	Navy Training	6%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-30: Estimated Effects to the West Coast Transient Stock of Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Sonar	Navy Training	19	27	-	-	-
Sonar	Navy Testing	7	1	-	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**27**	**28**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
349	0.16	0.00

	Percent of Total Effects		
Season	SOCAL	PMSR	NOCAL
Warm	2%	21%	33%
Cold	1%	19%	25%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	53%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	15%
Acoustic and Oceanographic Research (ONR)	Navy Testing	11%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-31: Estimated Effects to the Hawaii Stock of Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	-	0	0	-	-
Sonar	Navy Training	41	62	-	-	-
Sonar	Navy Testing	14	8	-	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**57**	**70**	**0**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
198	0.64	0.00

Season	HRC	High Seas
	Percent of Total Effects	
Warm	47%	2%
Cold	48%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	45%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	7%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.9 False Killer Whale (*Pseudorca crassidens*)*

False killer whales are in the HF cetacean auditory group and the Odontocete behavioral group. Four false killer whale populations are in the Study Area –the Main Hawaiian Islands Insular stock (Main Hawaiian Islands Insular DPS – endangered), the Hawaii Pelagic stock, the Northwestern Hawaiian Islands stock, and the Eastern Tropical Pacific population (not a designated stock).

2.4.2.9.1 ESA-listed False Killer Whales (Main Hawaiian Islands Insular DPS)

Model-predicted impacts are presented in Table 2.4-33.

The Main Hawaiian Islands Insular stock (Main Hawaiian Islands Insular DPS) of false killer whales is resident to the main Hawaiian Islands consisting of Kauai, Oahu, Molokai, Lanai, Kahoolawe, Maui, and Hawaii. This stock has two hierarchical (parent and child) small and resident population BIAs. The child BIA represents high use areas, specifically between Oahu and Molokai, to the west of Lanai, and to the northwest of the Island of Hawaii, encompassing the waters around the Hawaiian Islands. The series of areas that compose the child BIA are geographically located within the larger parent BIA. Although they have been tracked up to 115 km from the Hawaiian Islands, they generally stay within 72 km from shore. The Main Hawaiian Islands Insular stock of false killer whale may be impacted in the designated BIAs, particularly the larger parent BIA. This stock of false killer whales has year-round density estimates on the Hawaii Range Complex, which overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Most impacts would be behavioral responses. Impacts from explosives are limited, and there would be no impacts due to air guns. There are no auditory or non-auditory injuries predicted for this stock.

The potential for repeated impacts on individual false killer whales in the Main Hawaiian Islands Insular stock (Main Hawaiian Islands Insular DPS) in the Study Area is very low. On average, Individuals in this stock would be impacted once per year, and no risk of injury is predicted.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes that are income breeders, false killer whales are likely somewhat resilient to missed foraging opportunities due to acoustic disturbance but may be vulnerable to impacts during lactation. In addition, because of their longer generation times, false killer whales would require more time to recover if significantly impacted. Since the Main Hawaiian Islands stock of false killer whales are resident-nomadic, the risk of repeated exposures to individuals in this stock is likely similar within the population as animals move throughout their range.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals. Long-term consequences to the Main Hawaiian Islands Insular stock of false killer whales are unlikely.

Based on the analysis presented above, explosives and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, the Main Hawaiian Islands Insular DPS of false killer whales. The use of sonars during training activities may affect, and are likely to adversely affect, the Main Hawaiian Islands Insular DPS of false killer whales. Activities that involve the use of pile driving are not applicable to the Main Hawaiian Islands Insular DPS of false killer whales because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, the Main Hawaiian Islands Insular DPS of false killer whales. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, the Main Hawaiian Islands Insular DPS of false killer whales. Noise produced by air guns would have no effect on the Main Hawaiian Islands Insular DPS of false killer whales. Pile diving activities are not conducted during testing.

Critical Habitat

The critical habitat designated by NMFS for the main Hawaiian Islands insular false killer whales (83 *Federal Register* 35062) surrounds the islands of Niihau east to Hawaii from the 45-m to the 3,200-m depth contours. The main Hawaiian Islands insular DPS critical habitat is located entirely in the Hawaii Range Complex. A map of this critical habitat is in the *Biological Resources Supplemental Information*. Sound or energy from sonars, vessels, aircrafts, weapons, air guns, and explosives during military readiness activities could overlap this designated critical habitat. Pile driving would not occur in the Hawaii Range Complex, thus no overlap with pile driving noise would occur.

The essential feature for the conservation of the main Hawaiian Islands insular false killer whale is the following: *Island-associated marine habitat for main Hawaiian Islands insular false killer whales.* The critical habitat has four characteristics. Characteristics (1), *adequate space for movement and use within shelf and slope habitat,* and (3), *waters free of pollutants of a type and amount harmful to main Hawaiian Islands insular false killer whales,* would not be affected by sound or energy produced during military readiness activities and are not discussed further. The remaining characteristics may be affected by sound or energy produced during military readiness activities, as follows:

Characteristic (2) - *prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth*:

False killer whales are top predators that feed on a variety of large pelagic fish and squid. While use of sonar and noise produced by vessels, aircraft, and weapons firing would overlap critical habitat, they would not affect the second characteristic. Non-impulsive sound sources, such as sonars, have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007) and would only be expected to result in behavioral reactions or potential masking in fishes (see the *Fishes Background* section). Most sonar sources proposed for use during military readiness activities that would overlap or be adjacent to critical habitat would not fall within the frequency range of fish or squid hearing, thereby presenting no plausible route of effect on prey species; however, low frequency sources comprise approximately 18% of the bin hours and 30% of the bin counts in these areas. Squids, like most fish species, can detect low frequency sounds and would not perceive most mid- and all high frequency sonars. The few sources used within fish hearing range would be limited and typically transient (see Section 4 [*Impacts on Fishes from Acoustic and Explosive Stressors*]).

Limited use of air guns could occur in critical habitat. Air guns may affect prey species very close to the source, although the air guns used during testing are less powerful than those used in seismic surveys. Any impacts would be minimal, localized, and would not reduce overall aggregations of prey species.

Use of explosives may kill or injure nearby prey species. Explosives would not be used in the Hawaii Island Mitigation Area and the 4-Islands Mitigation area. These areas encompass nearly all critical habitat around Hawaii Island and a portion of critical habitat in the 4-islands region (see maps of the areas in *Mitigation*). Explosives would typically not occur within 12 NM of shore except in designated areas described in Appendix H (Description of Systems and Ranges) in the HCTT EIS/OEIS. Fish not killed or injured by an explosion might change their behavior, feeding pattern, or distribution. Stunning from pressure waves could also temporarily immobilize fish, making them more susceptible to predation. Most explosives would detonate at the water surface, including large gun projectiles, bombs, and missiles. As described in Section 4 [*Impacts on Fishes from Acoustic and Explosive Stressors*], the average range to fish mortality due to a bin E12 (> 675–1,000 lb. NEW) explosive, the largest explosive proposed in the false killer whale critical habitat, is up to 760 m. Ranges to effect for surface explosions are over-estimated as described in Section 2.5.4 (Ranges to Effects for Explosives). Although approximately 6,000 bin-counts of explosives are proposed in the Hawaii Range Complex, critical habitat overlaps only six percent of the area. Higher explosive weight bins (≥ E8 [i.e., ≥ 60 lb. NEW]) comprise less than five percent of the explosives in the Hawaii Range Complex and would typically be used in scheduled offshore subareas in the Hawaii Range Complex outside of critical habitat. Just under half of the explosives used in the area would have very low explosive weight bins (E1-E2 [i.e., ≤ 0.5 lb. NEW]) and over 90 percent of the explosives used in the area would be in explosive weight bin E5 or lower (i.e., ≤ 10 lb. NEW). Considering the mitigation areas and the limited overlap with locations in the Hawaii Range Complex where explosives could be used, effects on critical habitat are unlikely to affect prey of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth.

Characteristic (4) - sound levels that will not significantly impair false killer whales' use or occupancy:

False killer whales rely on their ability to receive and interpret sound in their environment to forage, travel and communicate with one another. Per the final rule designating critical habitat, *noises that would significantly impair use or occupancy are those that inhibit false killer whales' ability to receive and interpret sound for the purposes of navigation, communication, and detection of predators and prey. Such noises are likely to be long-lasting, continuous, and/or persistent in the marine environment and, either alone or added to other ambient noises, significantly raise local sound levels over a significant portion of an area*.

Sounds attributable to military readiness activities like sonar and explosives can be widely dispersed or concentrated in small areas for varying periods. See the section titled *Anthropogenic Noise* in the *Marine Mammal Acoustic Background* for additional information on the sound properties produced from military sonar and explosives. During military readiness activities, sound can cause masking in false killer whales, particularly from high-duty sonar sources, as described in the Impacts from Sonars and Other Transducers section. Masking occurs when a noise interferes with an animal's ability to perceive or discriminate sounds and signals that are biologically relevant.

The sonar bins in the proposed action include sources with a range of source levels, frequencies, and duty cycles. Sonars used during military readiness activities would not be "long-lasting" or "persistent," as their use in any event would be limited to the activity durations described in *Activity Descriptions*. Sonars used during military readiness activities, however, can be "continuous" and can "raise local sound levels." Characteristics of sources that may affect critical habitat are high duty cycles and high source levels in the frequencies most relevant for false killer whale communication and foraging. Hearing measurements of a false killer whale showed a hearing range between 4-50 kHz with best sensitivity between 16 and 24 kHz (Yuen et al., 2007). False killer whales produce echolocation clicks, whistles, and burst pulses. Whistle frequencies are between 4 and 8 kHz and echolocation clicks are between 17 and 32 kHz (Thode et al., 2016). Mid-frequency sonars (1 – 10 kHz) and high frequency sonars (10-100 kHz) overlap these frequency ranges.

While signals relevant to false killer whales may be masked by low (e.g. sounds of prey), mid- (e.g. communication calls), and high (e.g. foraging echolocation clicks) frequency sonars, the duty cycle of most active sonars is low enough that the sounds would be masked by only a small percentage of the time. Active sonar is duty-cycled such that it emits sound for a short period of time and then stops, usually for a much longer period for any return echoes to be received and interpreted. The typical duty cycle with most tactical anti-submarine warfare is about once per minute with most active sonar pulses lasting no more than a few seconds. Large scale training events (e.g., RIMPAC, USWEX, etc.) using the more powerful hull-mounted sonars would generally occur outside of critical habitat. High frequency sonars are generally lower powered than mid-frequency sonars, have shorter propagation ranges due to greater signal attenuation in the ocean, and are often used in directional sources rather than omni-directional sources. They are typically used for mine hunting, navigation, and object detection. Thus, while they can contribute to a reduction in communication space and detection space for foraging, the affected area would be both temporally and spatially limited. High frequency sonars associated with mine warfare activities would be more common in or near main Hawaiian Islands false killer whale critical habitat due to the shallow water needed in searching for mine shapes. he transitory nature of most training and testing activities ensures that any masking occurring within an area is of short duration.

Although any bin category could be used in critical habitat, a Navy review of classified data for typical sources (MF1, MF4, MF5) from 2012-2017 demonstrated that most use was outside of critical habitat. To assess the potential for sonars to affect main Hawaiian Islands false killer whale critical habitat under this proposed action, the portion of high duty-to-continuous duty cycle sonar use that is proposed in the Hawaii Range Complex that may occur in critical habitat is estimated. The main Hawaiian Island false killer whale critical habitat overlaps approximately 6 percent of the Hawaii Range Complex. Approximately 22,600 sonar bin-hours and 13,000 sonar bin-counts are proposed in the Hawaii Range Complex in a maximum year of activity in areas that completely or partially overlap[4] the critical habitat. These quantities do not include sonar use proposed in areas that were excluded from the designation of critical habitat[5] and areas subject to the Joint Base Pearl Harbor-Hickam Integrated Natural Resource Management Plan[6]. It is likely that a large portion of these sonar hours and counts would be used outside of critical habitat, since 94 percent of the Hawaii Range Complex does not overlap the critical habitat. Sonar bins are accounted for as both hours and counts. Sonars that are quantified as counts are typically those with a limited and relatively defined duration, such as dipping sonar or torpedoes. Approximately 2 percent of sonar bin-counts and a small portion bin-hours (see Table 2.4-32) employ high-to-continuous duty cycle sources, particularly in mid- and high frequencies that are relevant to false killer whale communication, foraging, and hearing.

[4] Areas of partial overlap with main Hawaiian Islands false killer whale critical habitat include the navigation track out of Pearl Harbor (south of the Naval Defense Area), W-186, and W-189.

[5] The national security exclusions include PMRF Offshore ranges (including the Shallow Water Training Range, the Barking Sands Tactical Underwater Range (BARSTUR), and the Barking Sands Underwater Range Extension (BSURE; west of Kauai), the Navy Kingfisher Range (northeast of Niihau), Warning Area 188 (west of Kauai), Kaula Island and Warning Area 187 (surrounding Kaula Island), the Navy Fleet Operational Readiness Accuracy Check Site (FORACS) (west of Oahu), the Navy Shipboard Electronic Systems Evaluation Facility (SESEF) (west of Oahu), Warning Areas 196 and 191 (south of Oahu), Warning Areas 193 and 194 (south of Oahu), the Kaulakahi Channel portion of Warning area 186 (the channel between Niihau and Kauai and extending east), the area north of Molokai (found offshore at the outer edge of the designation), the Alenuihaha Channel, the Hawaii Area Tracking System, and the Kahoolawe Training Minefield.

[6] Includes Ewa Training Minefield and the Naval Defensive Sea Area.

Table 2.4-32: Portion of Overall Sonar Use in in the Hawaii Range Complex with High to Continuous Duty Cycles

Source Class Category[1]	*Description*	*Duty Cycle*	*Percent*
Broadband Sources[2]			
LF	<205 dB	High	-
LF to HF		Continuous	2%
		High	3%
LF to MF		High	0%
MF to HF		High	18%
Low-Frequency Acoustic Sources			
LFL	160 dB to 185 dB	High	0%
LFM	185 dB to 205 dB	Continuous	0%
		High	12%
LFH	>205 dB	Continuous	0%
		High	2%
Mid-Frequency Acoustic Sources Other Than Hull-Mounted			
MFL	160 dB to 185 dB	High	2%
MFM	185 dB to 205 dB	Continuous	0%
		High	2%
MFH	>205 dB	Continuous	0%
		High	0%
Hull-Mounted Surface Ship Sonar			
MF1C	Hull-mounted surface ship sonar (previously MF11) with duty cycle >80%	High	2%
High-Frequency Acoustic Sources			
HFL	160 dB to 185 dB	High	0%
HFM	185 dB to 205 dB	Continuous	0%
		High	2%
HFH	>205 dB	Continuous	0%
		High	0%
Very High-Frequency Acoustic Sources			
VHFL	160 dB to 185 dB	High	-
VHFM	185 dB to 205 dB	High	-
VHFH	>205 dB	Continuous	0%
		High	0%

(-) means no hours or counts are proposed in this category in these areas.
[1] Bin MF1 and MF1K (hull-mounted sonar) are not included because they have a low duty cycle.
[2] Broadband sources have a range of duty cycles. For this analysis, they are all assumed to be high-to-continuous, which is an over-estimate.

Explosions could also mask hearing thresholds in marine mammals that are nearby, since explosions introduce low-frequency, broadband sounds into the environment. Sounds from explosions could also mask biologically relevant sounds. Certain activities with multiple detonations such as some naval gunfire exercises may create brief periods of broadband masking of biologically relevant sounds. However, the likelihood of substantial auditory masking from explosives is unlikely since the duration of individual explosive sounds is very short and behavioral impacts from explosives (e.g., mine countermeasure testing) on the critical habitat are negligible. See the sections titled *Masking* in the *Marine Mammal Acoustic Background* for additional information.

Mitigation areas in Hawaii limit the use of sonar and explosives nearshore. The geographic mitigation related to the use of active sonar off Hawaii Island states that Action Proponents will not use more than 300 hours of MF1 surface ship hull-mounted mid-frequency active sonar or 20 hours of helicopter dipping sonar (a mid-frequency active sonar source) annually within the Hawaii Island Marine Mammal Mitigation Area. MF1 surface ship hull-mounted mid-frequency active sonar will not be used within the Hawaii 4-Islands Marine Mammal Mitigation Area between mid-November to mid-April. Action Proponents will also not detonate in-water explosives (including underwater explosives and explosives deployed against surface targets) within the Hawaii Island Marine Mammal Mitigation Area and the Hawaii 4-Islands Marine Mammal Mitigation Area (see *Mitigation* for more details). These areas encompass nearly all critical habitat around Hawaii Island and a portion of critical habitat in the 4-islands region (see maps of the areas in *Mitigation*). Explosives would typically not occur within 12 NM of shore except in designated areas described in Appendix H (Description of Systems and Ranges) in the HCTT EIS/OEIS.

Vessel, aircraft, and weapons noise during training activities would have <u>no effect</u> on designated critical habitats in Hawaii for the Hawaiian Islands Insular DPS false killer whales. The use of sonars and explosives during training activities <u>may affect, but are not likely to adversely affect</u>, designated critical habitats for the Hawaiian Islands Insular DPS false killer whales. Activities that involve the use of pile driving are <u>not applicable</u> to false killer whale critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.

Vessel, aircraft, and weapons noise during testing activities would have <u>no effect</u> on designated critical habitats in Hawaii for the Hawaiian Islands Insular DPS false killer whales. The use of sonars, air guns, and explosives during testing activities <u>may affect, but are not likely to adversely affect</u>, designated critical habitats for the Hawaiian Islands Insular DPS false killer whales. Pile diving activities are not conducted during testing.

Table 2.4-33: Estimated Effects to the Main Hawaiian Islands Insular Stock of False Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	-	0	-	-	-
Explosive	Navy Testing	(1)	(1)	-	-	-
Sonar	Navy Training	68	54	-	-	-
Sonar	Navy Testing	32	9	-	-	-
Sonar	USCG Training	4	-	-	-	-
Maximum Annual Total		**105**	**64**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
138	1.22	0.00

Season	Percent of Total Effects
	HRC
Warm	53%
Cold	47%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	32%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	7%
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	Critical Habitat (All)	31	1	-	-	-
S-BIA-C	Main Hawaiian Islands (All)	8	-	-	-	-
S-BIA-P	Main Hawaiian Islands (All)	54	12	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.9.2 Non-ESA-listed False Killer Whales

Model-predicted impacts are presented in Table 2.4-34, Table-2.4-35, and Table 2.4-36.

Although false killer whales have stranded in Southern California, they are not included by NMFS as a managed species in California waters and are not expected to be present in California unless an El Niño event occurs. However, this species does have a density estimate in warmer waters off the Baja California Peninsula, Mexico within the HCTT Study Area. The lack of quantitative seasonal information on this Eastern Tropical Pacific population resulted in false killer whale density estimates being applied year-round. The estimated density for the California-Mexico population of false killer whales in the SOCAL Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this population are due to these activities. Impacts from explosives would be limited, and there would be no impacts due to air guns.

False killer whales congregate in deep oceanic waters off Hawaii and throughout the Pacific. They are commonly found in Hawaii in groups of up to 100 individuals in various depths and distances from shore. The Hawaii Pelagic stock of false killer whales has year-round density estimates on the Hawaii Range Complex, which overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and there would be no impacts due to air guns.

The Northwestern Hawaiian Islands stock of false killer whales have been seen as far as 93-km from Kauai, Niihau, and the Northwestern Hawaiian Islands, and do not have density estimates near the eastern Hawaiian Islands. There is a year-round. non-hierarchical small and resident population BIA designated for the Northwestern Hawaiian Islands stock of false killer whales that surrounds the northwest islands of Kauai and Niihau and extends farther northwest offshore. False killer whales may be impacted while in this designated BIA. This stock of false killer whales has year-round density estimates on the Hawaii Range Complex, which overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Most impacts would be behavioral responses. There are no auditory or non-auditory injuries from sonar or impacts from explosives predicted for this stock. There would be no impacts due to air guns.

On average, individuals in the Hawaii Pelagic stock and the Northwestern Hawaiian Islands stock would be impacted less than once per year, and individuals in the California-Mexico population would be impacted about once per year. The average individual risk of injurious impacts in these three populations is negligible. The modeled risk of an auditory injury in the Hawaii Pelagic stock from sonar testing is low (less than one) in any year, and the modeled risk of auditory injury in the Eastern Tropical Pacific population from sonar training and USCG explosive training is low (less than one) in any year. Single auditory injuries are shown in the maximum year of impacts for these stressors per the summation and rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of auditory injury may also be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As medium-sized odontocetes that are income breeders, false killer whales are likely somewhat resilient to missed foraging opportunities due to acoustic disturbance but may be vulnerable to impacts during lactation. In addition, because of their longer generation times, false killer whales would require more time to recover if significantly impacted. Since the Northwestern Hawaiian Islands stock of false killer whales are resident-nomadic, this could contribute to their slightly higher risk of repeated exposure compared to the Hawaii pelagic stock of false killer whales that are strictly nomadic and have less site fidelity within the Hawaii portion of the Study Area. As a result, the risk of repeated exposures to individuals in the Hawaii pelagic stock is likely similar within the population as animals move throughout their range.

A couple instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals that experience auditory injury may incur energetic costs. Based on the above analysis, long-term consequences for the Eastern Tropical Pacific population and the Hawaii Pelagic, and Northwestern Hawaiian Islands stocks of false killer whales are unlikely.

Table 2.4-34: Estimated Effects to the Eastern Tropical Pacific Population of False Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	0	1	-	-	-
Explosive	Navy Testing	0	(1)	0	0	-
Explosive	USCG Training	(1)	-	(1)	-	-
Sonar	Navy Training	1,361	765	(1)	-	-
Sonar	Navy Testing	332	60	0	-	-
Sonar	USCG Training	16	-	-	-	-
Maximum Annual Total		**1,710**	**827**	**2**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,990	1.28	0.00

Season	Percent of Total Effects
	SOCAL
Warm	42%
Cold	58%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	35%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	11%
Composite Training Unit Exercise (Strike Group)	Navy Training	9%
Medium Coordinated Anti-Submarine Warfare	Navy Training	7%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table-2.4-35: Estimated Effects to the Hawaii Pelagic Stock of False Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	(1)	-	-	-
Explosive	Navy Testing	0	0	0	-	-
Sonar	Navy Training	731	638	0	-	-
Sonar	Navy Testing	192	95	(1)	-	-
Sonar	USCG Training	12	-	-	-	-
Maximum Annual Total		**936**	**734**	**1**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
5,528	0.30	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	45%	2%
Cold	50%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	33%
Submarine Sonar Maintenance and Systems Checks	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-36: Estimated Effects to the Northwestern Hawaiian Islands Stock of False Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Sonar	Navy Training	96	55	-	-	-
Sonar	Navy Testing	30	8	-	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**128**	**63**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
477	0.40	0.00

Season	Percent of Total Effects: HRC
Warm	32%
Cold	68%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	24%
Medium Coordinated Anti-Submarine Warfare	Navy Training	20%
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	14%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Northwestern Hawaiian Islands (All)	83	25	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.10 Pygmy Killer Whale (*Feresa attenuata*)

Pygmy killer whales are in the HF cetacean auditory group and the Odontocete behavioral group. Two pygmy killer whale populations are in the Study Area – the Hawaii stock and the California population (not a designated stock). Model-predicted impacts are presented in Table 2.4-37 and Table 2.4-38.

Throughout the North and West Pacific, pygmy killer whales are generally an open ocean deepwater species. However, two year-round, non-hierarchical small and resident population BIAs have been delineated for pygmy killer whales in Hawaii. One pygmy killer whale BIA surrounds Oahu and Maui Nui, and the second BIA surrounds the southwestern portion of the Island of Hawaii. Although they the Hawaii stock of pygmy killer whales likely congregates in these two areas within the Hawaii portion of the HCTT Study Area, this stock has a uniform density value which was applied throughout the Hawaii Range Complex. Pygmy killer whale behavior may be impacted within these BIAs, particularly the Oahu-Maui Nui BIA. The Hawaii stock's year-round density in Hawaiian waters overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

Although pygmy killer whales have been sighted in offshore waters of Southern California, they are not included by NMFS as a managed species in California waters and are not expected to regularly occur in the area. However, this species does have a conservative density estimate in Southern California for summer and fall. The estimated density for the California population of pygmy killer whales in the SOCAL Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this population are due to these activities. Impacts from explosives and air guns would be negligible. No impacts are predicted during colder months (winter and spring) when the California population of pygmy killer whales would not be in the Study Area.

On average, individuals in the Hawaii stock and the California population would be impacted less than once per year. The average individual risk of injurious impacts in both populations is negligible. No auditory injuries are predicted for the California population, but a small number of auditory injuries could occur to individuals in Hawaii. However, the risk of auditory injuries in Hawaii from explosive training or sonar testing is low (less than one) in any year, but for each stressor, a single auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Little is known about pygmy killer whale demographics, but they are income breeders with a small body and medium pace of life, suggesting they are less resilient to missed foraging opportunities due to acoustic disturbance, especially during lactation. Since they have a nomadic-resident movement ecology, both stocks of pygmy killer whales move within their range year-round.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals that experience auditory injury may incur energetic costs. Based on the above analysis, long-term consequences for the Hawaii stock and California population of pygmy killer whales are unlikely.

Table 2.4-37: Estimated Effects to the California Population of Pygmy Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	(1)	(1)	-	-	-
Explosive	Navy Testing	-	(1)	0	0	-
Sonar	Navy Training	357	118	-	-	-
Sonar	Navy Testing	260	53	-	-	-
Sonar	USCG Training	3	-	-	-	-
Maximum Annual Total		**622**	**173**	**0**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
874	0.91	0.00

Season	Percent of Total Effects: SOCAL	PMSR	High Seas
Warm	84%	8%	7%
Cold	0%	0%	0%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	15%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	9%
Medium Coordinated Anti-Submarine Warfare	Navy Training	8%
Vehicle Testing	Navy Testing	8%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	7%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	6%
At-Sea Sonar Testing	Navy Testing	5%
Composite Training Unit Exercise (Strike Group)	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-38: Estimated Effects to the Hawaii Stock of Pygmy Killer Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	2	2	(1)	0	-
Explosive	Navy Testing	(1)	0	0	0	-
Explosive	Army Training	(1)	-	-	-	-
Sonar	Navy Training	3,666	3,758	1	-	-
Sonar	Navy Testing	928	481	(1)	-	-
Sonar	USCG Training	56	-	-	-	-
Maximum Annual Total		**4,654**	**4,241**	**3**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
11,928	0.75	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	47%	2%
Cold	48%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	35%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Submarine Sonar Maintenance and Systems Checks	Navy Training	10%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Hawaii Island (All)	1	0	-	-	-
S-BIA	Oahu-Maui Nui (All)	185	1	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.11 Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. The Hawaii stock of Fraser's dolphin is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-39.

Fraser's dolphins are one of the most abundant species within the Hawaiian Islands Exclusive Economic Zone. The Hawaii stock of Fraser's dolphins generally congregate in deep tropical waters with occurrence likely related to upwelling modified waters in the eastern tropical Pacific. The lack of quantitative seasonal information on this species resulted in Fraser's dolphin density estimates being applied year-round. In addition, the Hawaii stock of Fraser's dolphins has a uniform density value which was applied throughout this portion of the Study Area and the western portion of the transit corridor. Their estimated year-round density in Hawaiian waters overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. There would be no impacts due to air guns.

On average, individuals in the Hawaii stock would be impacted less than once per year, primarily due to behavioral responses. The average risk of injury is negligible, although a few auditory injuries and a single non-auditory injury are predicted. The risk of a non-auditory injury from either Navy explosive training or Army explosive training is low (less than one) in any year, but a non-auditory injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation, since this stock of Fraser's dolphins travel in large groups and have high sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Fraser's dolphins are income breeders with a small body and fast pace of life, suggesting they are less resilient to missed foraging opportunities due to acoustic disturbance, especially during lactation. This nomadic population moves within its range year-round. Therefore, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their Pacific range. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations would be quick to recover.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term consequences for individuals, although individuals who suffer an auditory or non-auditory injury may experience minor energetic costs. Based on the above analysis, long-term consequences for the Hawaii stock of Fraser's dolphins are unlikely.

Table 2.4-39: Estimated Effects to the Hawaii Stock of Fraser's Dolphin over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	13	10	3	(1)	-
Explosive	Navy Testing	0	0	0	-	-
Explosive	USCG Training	(1)	0	-	-	-
Explosive	Army Training	2	3	1	(1)	-
Sonar	Navy Training	16,259	14,089	1	-	-
Sonar	Navy Testing	3,562	1,524	(1)	-	-
Sonar	USCG Training	17	-	-	-	-
Maximum Annual Total		**19,854**	**15,626**	**6**	**2**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
47,288	0.75	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	48%	1%
Cold	49%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	32%
Submarine Sonar Maintenance and Systems Checks	Navy Training	17%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	12%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.12 Short-Finned Pilot Whale (*Globicephala macrorhynchus*)

Short-finned pilot whales are in the HF cetacean auditory group and the Odontocete behavioral group. Two short-finned pilot whale stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts on the California, Oregon, and Washington and the Hawaii stocks are presented in Table 2.4-40 and Table 2.4-41.

The California, Oregon, and Washington stock generally congregates in in warm temperate and tropical waters over the continental shelf break, in slope waters, and in areas of high topographic relief. In the absence of seasonally specific data, uniform density estimates for southern, central and northern California were used to represent this stock's density year-round. This is ecologically appropriate for short-finned pilot whales, since this is a nomadic species which follows the movements of their prey (e.g., squid) rather than a migration path. Intelligence, Surveillance, and Reconnaissance testing activities may employ lower source levels, but for longer periods and at frequencies where HF cetaceans are susceptible to auditory impacts. Surface Ship Detection and Anti-Submarine Warfare activities also contribute to impacts for the California, Oregon, and Washington stock. There would be no impacts due to air guns.

Most explosive impacts in California, including the model-predicted mortality, non-auditory injuries, and some of the auditory injuries are from Mine Neutralization Explosive Ordnance Disposal. The mortalities, non-auditory injuries, and auditory injuries associated with this activity may be mitigated, as the Navy conducts pre-event visual observations for mine warfare activities with placed explosives (see the *Mitigation* section). Adherence to these plans increases the likelihood that Lookouts would sight surface-active marine mammals, particularly species that occur in groups, and short-finned pilot whales tend to travel in large groups up to 50 individuals.

Short-finned pilot whales are found close to shore near oceanic islands like Hawaii, where the shelf is narrow and deeper waters are found nearby. A year-round small and resident population parent BIA and three child BIAs have been delineated for short-finned pilot whales in waters of the Main Hawaiian Island. Short-finned pilot whale behavior may be impacted within these BIAs, particularly the larger Main Hawaiian Island parent BIA and Western Community child BIA closer to Kauai, Niihau, and the west coast of Oahu. Short-finned pilot whale's year-round higher densities in nearshore Hawaiian waters overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. The number of impacts due to other acoustic stressors (i.e., explosives, air guns) would be limited.

On average, individuals in the California, Oregon, and Washington stock could be impacted several times per year, and individuals in the Hawaii stock could be impacted less than once per year. The average individual risk of injurious impacts in both populations is very low, although a small number of auditory and non-auditory injuries could occur to individuals in either stock and a single mortality could occur to a short-finned pilot whale in Southern California. However, the risk of an auditory injury in California from sonar testing, sonar training, or explosive testing is low (less than one) in any year, but a single injury from sonar testing, sonar training, and explosive testing is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Likewise, the risk of a non-auditory injury in Hawaii from Army explosive training is low (less than one) in any year, but a single non-auditory injury from Army explosive training is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach. These injuries are shown in the maximum year of impacts per the summation and rounding approach discussed above. The risk of injury or mortality may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Short-finned pilot whales are medium-sized, income breeding odontocetes with a slow pace of life, making them somewhat resilient to missed foraging opportunities due to acoustic disturbance, except for during lactation. Both populations are nomadic and move within their range year-round. Therefore, the risk of repeated exposures to individuals is likely similar within the population. However, because of their longer generation times, this population would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience auditory or non-auditory injury would incur energetic costs. Based on the above analysis, long-term consequences for the California, Oregon, and Washington and Hawaii stocks of short-finned pilot whales are unlikely.

Table 2.4-40: Estimated Effects to the California, Oregon, and Washington Stock of Short-Finned Pilot Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	6	6	6	2	1
Explosive	Navy Testing	2	2	(1)	-	-
Sonar	Navy Training	1,436	547	(1)	-	-
Sonar	Navy Testing	1,899	371	(1)	-	-
Sonar	USCG Training	10	-	-	-	-
Maximum Annual Total		**3,353**	**926**	**9**	**2**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
836	5.13	0.01

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	34%	3%	2%	1%
Cold	51%	6%	1%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	29%
Surface Ship Object Detection	Navy Training	9%
Mine Countermeasure Technology Research	Navy Testing	9%
Medium Coordinated Anti-Submarine Warfare	Navy Training	8%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	8%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-41: Estimated Effects to the Hawaii Stock of Short-Finned Pilot Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	6	9	1	0	0
Explosive	Navy Testing	4	3	1	-	-
Explosive	Army Training	2	1	(1)	(1)	-
Sonar	Navy Training	8,905	4,931	2	-	-
Sonar	Navy Testing	2,625	734	(1)	-	-
Sonar	USCG Training	83	-	-	-	-
Maximum Annual Total		**11,626**	**5,678**	**6**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
23,117	0.75	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	46%	1%
Cold	51%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	25%
Submarine Sonar Maintenance and Systems Checks	Navy Training	8%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	6%
Submarine Navigation	Navy Training	6%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Main Hawaiian Islands - Central Community (All)	25	2	-	-	-
S-BIA-C	Main Hawaiian Islands - Eastern Community (All)	11	11	-	-	-
S-BIA-C	Main Hawaiian Islands - Western Community (All)	1,682	358	0	-	-
S-BIA-P	Main Hawaiian Islands (All)	4,039	576	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.2.13 Melon-Headed Whale (*Peponocephala electra*)

Melon-headed whales are in the HF cetacean auditory group and the Odontocete behavioral group. Two melon-headed whale stocks are in the Study Area – the Hawaiian Islands stock and the Kohala resident stock. Model-predicted impacts are presented in Table 2.4-42 and Table 2.4-43.

Melon-headed whales congregate in deep tropical and subtropical waters, especially when they forage at night. However, they have been known to rest nearshore oceanic islands during the day. Melon-headed whales are regularly found within Hawaiian waters. The Hawaiian Islands stock of melon-headed whales includes melon-headed whales inhabiting waters throughout the Hawaiian Islands. The Hawaiian Islands stock's year-round higher densities in deep waters around the Hawaii Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives and air guns would be limited.

The Kohala resident stock of melon-headed whales are present year-round off the Kohala and west coast of Hawaii Island in waters less than 2,500 m deep. A year-round, non-hierarchical small and resident population BIA has been delineated for melon-headed whales off the Island of Hawaii which overlaps a large portion of this stock's range. Melon-headed whales may be impacted in this designated BIA. The Kohala resident stock's presence in the Hawaii Range Complex overlaps areas where Anti-

Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Because their range is substantially smaller and there are fewer melon-headed whales for this stock compared to the Hawaiian Islands stock, there are relatively fewer impacts on the Kohala resident stock. There would be no impacts due to air guns and impacts from explosives would be negligible.

On average, individuals in the Hawaiian Islands stock and the Kohala resident stock would be impacted less than once per year. The average individual risk of injurious impacts in both populations is negligible. No auditory or non-auditory injuries are predicted for the Kohala resident stock, but a small number of auditory injuries could occur to individuals in the Hawaiian Islands stock. The risk of an auditory injury in Hawaii from explosive testing is low (less than one) in any year, but a single auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through activity-based mitigation, especially since melon-headed whales tend to travel in large groups.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small odontocetes that are income breeders with a medium pace of life, melon-headed whales are likely somewhat resilient to missed foraging opportunities due to acoustic disturbance but could be vulnerable during lactation. Because the Hawaiian Islands stock is nomadic-resident and the Kohala stock is resident, the risk of repeated exposures to individuals is likely similar within the populations as animals move throughout their range. However, because of their longer generation times, these populations would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience auditory injury may incur energetic costs. Based on the above analysis, long-term consequences for the Hawaiian Islands and Kohala resident stocks of melon-headed whales are unlikely.

Table 2.4-42: Estimated Effects to the Hawaiian Islands Stock of Melon-Headed Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	4	3	1	0	0
Explosive	Navy Testing	1	(1)	(1)	0	-
Explosive	USCG Training	(1)	-	-	-	-
Explosive	Army Training	1	(1)	(1)	-	-
Sonar	Navy Training	12,560	13,553	8	-	-
Sonar	Navy Testing	3,396	1,711	2	-	-
Sonar	USCG Training	223	-	-	-	-
Maximum Annual Total		**16,187**	**15,269**	**13**	**0**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
46,949	0.67	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	45%	2%
Cold	51%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	37%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Submarine Sonar Maintenance and Systems Checks	Navy Training	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-43: Estimated Effects to the Kohala Resident Stock of Melon-Headed Whales over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Army Training	1	(1)	-	-	-
Sonar	Navy Training	15	8	-	-	-
Sonar	Navy Testing	25	6	-	-	-
Maximum Annual Total		**41**	**15**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
447	0.13	0.00

Season	Percent of Total Effects HRC
Warm	77%
Cold	23%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	40%
Vehicle Testing	Navy Testing	18%
Anti-Submarine Warfare Tracking Test (Rotary Wing)	Navy Testing	12%
At-Sea Sonar Testing	Navy Testing	9%
Acoustic and Oceanographic Research (ONR)	Navy Testing	7%
Torpedo (Non-Explosive) Testing	Navy Testing	7%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Kohala Residents - Hawaii Island (All)	20	5	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
version.20241107

2.4.2.14 Pacific White-Sided Dolphin (*Lagenorhynchus acutus*)

Pacific white-sided dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. One stock of Pacific white-sided dolphin is in the Study Area – the California, Oregon, and Washington stock. Model-predicted impacts are presented in Table 2.4-44.

The California, Oregon, and Washington stock of Pacific white-sided dolphins generally congregate in cold temperate waters over the continental shelf and slope from the southern Bering Sea to the Gulf of California off Mexico, with higher abundances in the northern portion of the HCTT Study Area, closer to Oregon and Washington. To a lesser extent, Pacific white-sided dolphins occur in Southern California year-round which overlap areas where Anti-Submarine Warfare and various testing activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would occur from a variety of activities. The few mortalities are predicted from these explosive activities are the combined prediction from multiple types of activities, primarily Mine Warfare. They have specific pre-event visual observation mitigations that may reduce the number of impacts on marine mammals in the area (see the *Mitigation* section for details). The risk of impacts due to air guns would be limited.

The potential for repeated impacts on individuals is low. On average, Individuals in the California, Oregon, and Washington stock would be impacted less than once per year. The average individual risk of injurious impacts is negligible, although several injuries and two mortalities are predicted. The modeled risk of a mortality from explosive testing or training is low (less than one) in any year, but a single mortality from both explosive testing and training is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). These mortalities are shown in the maximum year of impacts per the summation and rounding approach discussed above. The risk of injury or mortality may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small odontocetes that are income breeders with a medium pace of life, Pacific white-sided dolphins are likely somewhat resilient to missed foraging opportunities due to acoustic disturbance but could be vulnerable during lactation. This nomadic population moves within their range year-round, including northern habitats outside the Study Area, so the risk of repeated exposures to individuals within the population is likely similar year-round. However, because of their longer generation times, this species would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who suffer an auditory or non-auditory injury may experience energetic costs. The risk of mortality is extremely unlikely. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock of Pacific white-sided dolphins are unlikely.

Table 2.4-44: Estimated Effects to the California, Oregon, and Washington Stock of Pacific White-Sided Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	-	-	-	-
Explosive	Navy Training	77	73	16	3	(1)
Explosive	Navy Testing	25	31	6	1	(1)
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	22,095	19,683	14	-	-
Sonar	Navy Testing	23,127	3,851	2	-	-
Sonar	USCG Training	246	1	-	-	-
Maximum Annual Total		**45,571**	**23,639**	**38**	**4**	**2**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
107,775	0.64	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	20%	5%	17%
Cold	33%	12%	14%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	29%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	12%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	9%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	6%
Unmanned Underwater Vehicle Testing	Navy Testing	6%
Undersea Warfare Testing	Navy Testing	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
version.20241107

2.4.2.15 Pantropical Spotted Dolphin (*Stenella attenuata*)

Pantropical spotted dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. Five Pantropical spotted dolphin populations are in the Study Area –the Maui Nui stock (formerly the 4-Islands stock), the Hawaii Island stock, the Hawaii Pelagic stock, the Oahu stock, and the Baja, California Peninsula Mexico population (not a designated stock). Model-predicted impacts are presented in Table 2.4-45 through Table 2.4-49.

Pantropical spotted dolphins can be found mostly in deep offshore tropical and subtropical waters of the Pacific, but they do approach the coast in some areas like Hawaii. They are one of the most abundant species of cetacean in Hawaiian waters. A year-round small and resident population parent BIA and three child BIAs have been delineated for all stocks of pantropical spotted dolphins around the waters surrounding Oahu, Maui Nui, and the Island of Hawaii. The Maui Nui stock of pantropical spotted dolphins generally congregate in shallow coastal waters with depths from 1,500 to 3,500 m. Most impacts on the Maui Nui stock of pantropical spotted dolphins are predicted to occur within the designated BIAs, particularly the larger parent BIA. Their year-round higher densities in nearshore waters overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

The Hawaii Island stock of pantropical spotted dolphins generally congregate in shallow coastal waters with depths from 1,500 to 3,500 m. This stock of pantropical spotted dolphins may be impacted in the designated BIAs, particularly the larger parent BIA. Their year-round higher densities in nearshore waters overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives and air guns would be limited.

The Hawaii Pelagic stock of pantropical spotted dolphins can be found in tropical offshore waters of the Hawaiian Islands EEZ, with highest densities near all the islands, but particularly around the Main Hawaiian Islands. A new habitat-based density model was used which showed an increase in overall density for this stock compared to the previous analysis. The Hawaii Pelagic stock increased density estimates in the Hawaii Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives and air guns would be limited.

The Oahu stock of pantropical spotted dolphins generally congregate in shallow coastal waters with depths from 1,500 to 3,500 m. Most impacts on the Oahu stock of pantropical spotted dolphins are predicted to occur within the designated BIAs. Their year-round higher densities in nearshore waters overlap areas where sonar activities like Submarine Navigation, Surface Ship Object Identification, and Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Most impacts would be behavioral. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

The Baja, California Peninsula Mexico population of pantropical spotted dolphins can be found in tropical and subtropical waters deep offshore. They are not expected to occur in waters off California or the eastern portion of the transit corridor but may occur in waters off the BCPM within the HCTT Study Area. The lack of quantitative seasonal information on this population resulted in pantropical spotted dolphins density estimates being applied year-round. This population of pantropical spotted dolphins in the SOCAL Range Complex overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this population are due to these activities. Impacts from explosives are limited, although two mortalities are predicted due to the combined risk from offshore explosive activities. Impacts from air guns would be limited.

On average, individuals in the Oahu stock could be impacted several times per year, and individuals in the Maui Nui stock, the Hawaii Island stock, and the Hawaii Pelagic stock would be impacted less than once per year. On average, individuals in the Baja, California Peninsula Mexico population would be impacted less than twice per year. The average individual risk of injury is negligible in all five populations, but a small number of injuries could occur to individuals in any of the five populations of pantropical spotted dolphins. In addition, mortalities are predicted for Baja, California Peninsula Mexico population. The risk of a mortality from explosive testing and training is low (less than one) in any year for this population, but single mortalities are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Similarly, the risk of non-auditory injuries is low (less than one) in any year in most instances for each of the stocks/population, but single non-auditory injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed above. The risk of injury and mortality may be reduced through visual observation mitigation, especially since Pantropical spotted dolphins tend to travel in large groups.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small odontocete income breeders with a medium pace of life, Pantropical spotted dolphins are likely somewhat resilient to missed foraging opportunities due to acoustic disturbance. Because nomadic and offshore populations of pantropical spotted dolphins like the Hawaii Pelagic stock have a larger range farther from shore, they have a lower risk of repeated exposure compared to the other three nearshore residential stocks in the Hawaii portion of the Study Area. The Oahu stock of pantropical spotted dolphins has the smallest range out of the three residential stocks, which combined with more activities occurring there, likely contributed to the higher risk of repeated exposure shown below.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience auditory or non-auditory injury may incur energetic costs. The risk of mortality is extremely unlikely. Based on the above analysis, long-term consequences for the Maui Nui stock, the Hawaii Island stock, the Hawaii Pelagic stock, the Oahu stock, and the Baja, California Peninsula Mexico population of Pantropical spotted dolphins are unlikely.

Table 2.4-45: Estimated Effects to the Maui Nui (Formerly 4 Islands) Stock of Pantropical Spotted Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	3	2	2	0	-
Explosive	Navy Testing	19	8	1	0	-
Explosive	Army Training	-	(1)	-	-	-
Sonar	Navy Training	811	14	-	-	-
Sonar	Navy Testing	1,358	157	(1)	-	-
Maximum Annual Total		**2,191**	**182**	**4**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
2,674	0.89	0.00

Season	Percent of Total Effects HRC
Warm	50%
Cold	50%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Surface Ship Object Detection	Navy Training	27%
Anti-Submarine Warfare Tracking Test (Rotary Wing)	Navy Testing	21%
Vehicle Testing	Navy Testing	13%
Anti-Submarine Warfare Torpedo Test (Aircraft)	Navy Testing	11%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Oahu-Maui Nui-Hawaii Island - Maui Nui (All)	808	108	2	-	-
S-BIA-P	Oahu-Maui Nui-Hawaii Island (All)	2,170	181	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-46: Estimated Effects to the Hawaii Island Stock of Pantropical Spotted Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	1	8	2	(1)	-
Explosive	Navy Testing	(1)	(1)	(1)	-	-
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	2,086	2,879	2	-	-
Sonar	Navy Testing	789	234	(1)	-	-
Sonar	USCG Training	24	-	-	-	-
Maximum Annual Total		**2,902**	**3,122**	**6**	**1**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
8,674	0.70	0.00

	Percent of Total Effects
Season	HRC
Warm	51%
Cold	49%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	39%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	14%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	9%
Submarine Sonar Maintenance and Systems Checks	Navy Training	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Oahu-Maui Nui-Hawaii Island - Hawaii Island (All)	801	1,356	1	-	-
S-BIA-P	Oahu-Maui Nui-Hawaii Island (All)	1,253	1,612	1	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-47: Estimated Effects to the Hawaii Pelagic Stock of Pantropical Spotted Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	11	13	3	(1)	0
Explosive	Navy Testing	12	4	(1)	(1)	0
Explosive	USCG Training	-	(1)	-	-	-
Explosive	Army Training	2	1	(1)	(1)	0
Sonar	Navy Training	18,458	17,816	9	-	-
Sonar	Navy Testing	5,521	2,324	2	-	-
Sonar	USCG Training	226	-	-	-	-
Maximum Annual Total		**24,231**	**20,159**	**16**	**3**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
67,313	0.66	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	44%	2%
Cold	53%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	31%
Submarine Sonar Maintenance and Systems Checks	Navy Training	11%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	10%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-48: Estimated Effects to the Oahu Stock of Pantropical Spotted Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	17	15	3	(1)	-
Explosive	Navy Testing	-	(1)	0	-	-
Sonar	Navy Training	5,489	97	(1)	-	-
Sonar	Navy Testing	748	58	(1)	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**6,255**	**171**	**5**	**1**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,491	4.31	0.00

Season	Percent of Total Effects
	HRC
Warm	51%
Cold	49%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Navigation	Navy Training	48%
Surface Ship Object Detection	Navy Training	19%
Mine Countermeasures - Ship Sonar	Navy Training	17%
Anti-Submarine Warfare Tracking Test (Rotary Wing)	Navy Testing	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Oahu-Maui Nui-Hawaii Island - Oahu (All)	5,937	145	3	-	-
S-BIA-P	Oahu-Maui Nui-Hawaii Island (All)	6,196	147	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
version.20241107

Table 2.4-49: Estimated Effects to the Baja, California-Peninsula Mexico Population of Pantropical Spotted Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	2	-	-	-	-
Explosive	Navy Training	15	11	5	1	(1)
Explosive	Navy Testing	25	19	1	1	(1)
Explosive	USCG Training	-	(1)	-	-	-
Sonar	Navy Training	48,096	34,318	37	-	-
Sonar	Navy Testing	12,181	2,468	2	-	-
Sonar	USCG Training	490	-	-	-	-
Maximum Annual Total		**60,809**	**36,817**	**45**	**2**	**2**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
70,889	1.38	0.00

Season	Percent of Total Effects
	SOCAL
Warm	45%
Cold	55%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	34%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	12%
Composite Training Unit Exercise (Strike Group)	Navy Training	10%
Medium Coordinated Anti-Submarine Warfare	Navy Training	7%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
version.20241107

2.4.2.16 Striped Dolphin (*Stenella coeruleoalba*)

Striped dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. Two striped dolphin stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-50 and Table 2.4-51.

The California, Oregon, and Washington stock of striped dolphins generally congregates over deep, relatively warmer waters off the U.S. west coast. They appear to have a continuous distribution in offshore waters from California to Mexico, expanding north into PMSR only during warmer months (summer and fall). Their year-round higher densities in deep waters offshore Southern California and Baja California, Mexico, overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. The number of impacts from air guns and explosives are limited, although a mortality is predicted for the combined training activities.

Striped dolphins regularly occur in the warm tropical waters around the Hawaiian Islands. The Hawaii stock of striped dolphins is present year-round in waters primarily seaward of the 1,000-m depth contour, but they are occasionally sighted closer to shore, from a depth range of 100 to 1,000 m. Their year-round higher densities in warm waters offshore Hawaii overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. The number of impacts due to explosives and air guns would be limited.

On average, individuals in the California, Oregon, and Washington stock and the Hawaii stock would be impacted less than once per year. A small number of injuries could occur to individuals in either stock, although the average individual risk of injury is negligible. In addition, a single mortality could occur to individuals in the California, Oregon, and Washington stock. However, the risk of a mortality from explosives is low (less than one) in any year, but a mortality is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments The risk of injury may be reduced through visual observation mitigation, especially since striped dolphins tend to travel in large groups.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and medium pace of life, striped dolphins are somewhat resilient to missed foraging opportunities due to acoustic disturbance, except for during lactation. Striped dolphins are nomadic, so the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range year-round. Both stocks of striped dolphins have unknown population trends. Because of their longer generation times, this population would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience an auditory or non-auditory injury may incur energetic costs. The risk of mortality is extremely unlikely. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock and Hawaii stock of striped dolphins are unlikely.

Table 2.4-50: Estimated Effects to the California, Oregon, and Washington Stock of Striped Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	-	-	-	-
Explosive	Navy Training	12	23	4	1	(1)
Explosive	Navy Testing	16	22	4	1	0
Explosive	USCG Training	-	(1)	-	-	-
Sonar	Navy Training	63,661	46,945	32	-	-
Sonar	Navy Testing	16,581	5,362	2	-	-
Sonar	USCG Training	775	-	-	-	-
Maximum Annual Total		**81,046**	**52,353**	**42**	**2**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
160,551	0.83	0.00

Season	Percent of Total Effects: SOCAL	PMSR	High Seas
Warm	45%	5%	5%
Cold	42%	0%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	31%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	11%
Medium Coordinated Anti-Submarine Warfare	Navy Training	10%
Composite Training Unit Exercise (Strike Group)	Navy Training	9%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	7%
Vehicle Testing	Navy Testing	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
version.20241107

Table 2.4-51: Estimated Effects to the Hawaii Stock of Striped Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	-	(1)	-	-	-
Explosive	Navy Training	11	5	1	(1)	-
Explosive	Navy Testing	2	1	(1)	0	-
Explosive	USCG Training	-	0	0	-	-
Explosive	Army Training	1	2	(1)	(1)	-
Sonar	Navy Training	14,566	16,678	6	-	-
Sonar	Navy Testing	3,793	2,473	1	-	-
Sonar	USCG Training	247	2	-	-	-
Maximum Annual Total		**18,620**	**19,162**	**10**	**2**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
68,909	0.55	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	45%	3%
Cold	50%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	36%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	11%
Submarine Sonar Maintenance and Systems Checks	Navy Training	11%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
version.20241107

2.4.2.17 Spinner Dolphin (*Stenella longirostris*)

Spinner dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. Six Spinner dolphin stocks are in the Study Area – the Hawaii Island stock, Hawaii Pelagic stock, the Kauai and Niihau stock, the Oahu/4-Islands stock, the Kure and Midway stock, and the Pearl and Hermes Reef stock. Model-predicted impacts on the Hawaii Island stock, Hawaii Pelagic stock, the Kauai and Niihau stock, and the Oahu/4-Islands stock are presented in Table 2.4-52 through Table 2.4-55. There are no predicted impacts on the Kure and Midway stock or the Pearl and Hermes Reef stock.

The distribution of the Hawaii Island stock of spinner dolphins extends from the coast of Hawaii out to 10 nm from shore. Spinner dolphins in Hawaii have a higher abundance along the leeward coasts of all the major islands and around several of the atolls northwest of the main Hawaiian Islands in water shallower than 4,000 m in depth. They are expected to occur in shallow water resting areas (about 50 m deep or less) throughout the middle of the day, moving into deep waters offshore during the night to feed. Five year-round, non-hierarchical small and resident population BIAs have been delineated for spinner dolphins around several islands including the Island of Hawaii, where this stock is resident. Most impacts on the Hawaii Island stock of spinner dolphins are predicted to occur within the designated Island of Hawaii BIA. Their year-round higher densities in nearshore shallow waters around the Island of Hawaii overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

The Hawaii Pelagic stock of pantropical spotted dolphins is often found in waters with a shallow thermocline (rapid temperature difference with depth) which concentrates open sea organisms in and above it, which spinner dolphins feed on. The Hawaii Pelagic stock density estimates in the Hawaii Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

The Kauai and Niihau stock of spinner dolphins generally congregate in shallow coastal waters with depths from 50 to 4,000 m. A year-round, non-hierarchical small and resident population BIAs has been delineated for spinner dolphins around several islands, including Kauai and Niihau where this stock is resident. Most impacts on this stock of spinner dolphins are predicted to occur within the designated Kauai and Niihau BIA. The waters off Kauai are particularly popular for spinner dolphins. They are frequently found resting in Kilauea Bay, Kauai, and monitoring for a Naval exercise in 2006 resulted in daily sightings of spinner dolphins within the offshore area of Kauai, near the PMRF. Their higher densities in nearshore tropical waters overlap areas where Anti-Submarine Warfare activities would occur, particularly in colder months. Most sonar impacts on this stock are due to these activities. Impacts from explosives would be limited, and no impacts are predicted due to air guns.

The Oahu/4-Islands stock of spinner dolphins generally congregates in shallow coastal waters with depths from 50 to 4,000 m. Five year-round, non-hierarchical small and resident population BIAs have been delineated for spinner dolphins around several islands including islands where this stock is resident (e.g., Oahu/Maui Nui). Most impacts on this stock of spinner dolphins are predicted to occur within the designated Oahu and Maui Nui BIA. Their year-round higher densities in nearshore tropical waters overlap areas where submarine navigation activities would occur. Impacts from explosives would be limited, and no impacts are predicted due to air gun.

On average, individuals in the Hawaii Island stock and Hawaii Pelagic stock would be impacted less than once per year, and individuals in the Kauai and Niihau stock and the Oahu/4-Islands stock could be impacted several times per year. The average individual risk of injury is negligible in all four stocks, but a small number of auditory injuries could occur. However, in four out of six instances of auditory injury, the risk of an injury is low (less than one) in any year, but single injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Therefore, the risk of any auditory injury from an explosive activity is unlikely for all stocks of spinner dolphins in the HCTT Study Area, and the risk of an auditory injury from sonar testing is unlikely for spinner dolphins in the Hawaii pelagic stock. The risk of injury may be reduced through visual observation mitigation, as spinner dolphins have relatively higher sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and a fast pace of life, spinner dolphins are less resilient to missed foraging opportunities due to acoustic disturbance, especially during lactation. Because this stock is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. The population trend for all stocks of spinner dolphins in the HCTT Study Area are unknown. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations are quick to recover.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience auditory injury may incur energetic costs. Based on the above analysis, long-term consequences for the Hawaii Island stock, Hawaii Pelagic stock, the Kauai and Niihau stock, and the Oahu/4-Islands stock of spinner dolphins are unlikely.

Table 2.4-52: Estimated Effects to the Hawaii Island Stock of Spinner Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	1	(1)	(1)	0	-
Explosive	Navy Testing	0	-	-	-	-
Sonar	Navy Training	46	49	-	-	-
Sonar	Navy Testing	13	0	-	-	-
Maximum Annual Total		**60**	**50**	**1**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
670	0.17	0.00

Season	Percent of Total Effects: HRC
Warm	60%
Cold	40%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	76%
Vehicle Testing	Navy Testing	7%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Hawaii Island (All)	57	49	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-53: Estimated Effects to the Hawaii Pelagic Stock of Spinner Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	(1)	(1)	0	0	-
Explosive	Navy Testing	0	(1)	0	0	-
Sonar	Navy Training	1,679	2,100	1	-	-
Sonar	Navy Testing	473	265	(1)	-	-
Sonar	USCG Training	24	-	-	-	-
Maximum Annual Total		**2,177**	**2,367**	**2**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
6,807	0.67	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	43%	2%
Cold	52%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	39%
Submarine Sonar Maintenance and Systems Checks	Navy Training	10%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	10%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-54: Estimated Effects to the Kauai and Niihau Stock of Spinner Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	0	2	0	0	0
Explosive	Navy Testing	0	(1)	(1)	-	-
Sonar	Navy Training	2,660	866	1	-	-
Sonar	Navy Testing	901	16	-	-	-
Maximum Annual Total		**3,561**	**885**	**2**	**0**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
606	7.34	0.00

Season	Percent of Total Effects: HRC
Warm	35%
Cold	65%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	34%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	32%
Anti-Submarine Warfare Torpedo Exercise - Maritime Patrol Aircraft	Navy Training	11%
Undersea Range System Test	Navy Testing	10%
Long Range Acoustic Communications	Navy Testing	8%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Kauai and Niihau (All)	3,438	864	1	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-55: Estimated Effects to the Oahu /4 Islands Stock of Spinner Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	4	3	(1)	0	0
Explosive	Navy Testing	1	(1)	-	-	-
Sonar	Navy Training	971	13	-	-	-
Sonar	Navy Testing	180	28	0	-	-
Maximum Annual Total		**1,156**	**45**	**1**	**0**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
355	3.39	0.00

Season	Percent of Total Effects: HRC
Warm	63%
Cold	37%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Navigation	Navy Training	48%
Surface Ship Object Detection	Navy Training	18%
Mine Countermeasures - Ship Sonar	Navy Training	14%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Oahu and Maui Nui (All)	1,139	45	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
version.20241107

2.4.2.18 Rough-Toothed Dolphin (*Steno bredanensis*)

Rough-toothed dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. The Hawaii stock is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-56.

Rough-toothed dolphins are one of the most abundant species present in the Study Area and can be found in deep ocean waters off the Hawaiian Islands but are also seen relatively frequently during nearshore surveys. A large portion of the core area for the Hawaii stock of rough-toothed dolphins overlaps the PMRF range and the channel between Kauai and Niihau. A year-round small and resident population parent BIA and child BIA have been delineated for waters off Kauai, Niihau, and the west coast of Oahu for rough-toothed dolphins. In addition, a year-round, non-hierarchical BIA was delineated for rough-toothed dolphins associated with Maui Nui and the Island of Hawaii. Rough-toothed dolphins may be impacted within these BIAs, particularly the Kauai Niihau-Oahu parent BIA. Their year-round higher densities in waters in the Hawaii Range Complex overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Impacts from air guns and explosives are limited, although two mortalities are predicted from combined training activities and Mine Warfare testing activities.

On average, individuals in the Hawaii stock would be impacted less than once per year. A small number of auditory and non-auditory injuries could occur to individuals, although the average individual risk of injury is negligible. In addition, a mortality could occur from explosive testing and training activities. However, the risk of a single mortality from either activity is low (less than one) in any year, but a mortality for both explosive activities is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation, as rough-toothed dolphins are moderately sightable.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and a medium pace of life, rough-toothed dolphins have some resilience to missed foraging opportunities due to acoustic disturbance, except for during lactation. Because the Hawaii stock is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. The population trend for this stock is unknown, and because of their longer generation times, this population would require more time to recover if it was further significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. The risk of mortality is extremely unlikely. Based on the above analysis, long-term consequences for the Hawaii stock of rough-toothed dolphins are unlikely.

Table 2.4-56: Estimated Effects to the Hawaii Stock of Rough-Toothed Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	72	63	6	3	(1)
Explosive	Navy Testing	42	23	3	1	(1)
Explosive	USCG Training	0	-	-	-	-
Explosive	Army Training	3	2	(1)	(1)	-
Sonar	Navy Training	45,968	34,070	18	-	-
Sonar	Navy Testing	11,455	4,768	3	-	-
Sonar	USCG Training	406	-	-	-	-
Maximum Annual Total		**57,947**	**38,926**	**31**	**5**	**2**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
106,193	0.91	0.00

Season	Percent of Total Effects	
	HRC	High Seas
Warm	46%	2%
Cold	51%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	26%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	9%
Submarine Sonar Maintenance and Systems Checks	Navy Training	8%
Submarine Navigation	Navy Training	8%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Maui Nui-Hawaii Island (All)	677	351	0	-	-
S-BIA-C	Kauai Niihau-Oahu - Kauai Niihau (All)	4,996	1,688	2	-	-
S-BIA-P	Kauai Niihau-Oahu (All)	8,242	2,820	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
version.20241107

2.4.2.19 Northern Right Whale Dolphin (*Steno bredanensis*)

Northern right whale dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. The California, Oregon, and Washington stock is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-57.

Northern right whale dolphins generally have higher abundances in cold waters along the outer continental shelf and slope and move nearshore only in areas where the continental shelf is narrow or where productivity on the shelf is especially high. While the California, Oregon, and Washington stock of Northern right whale dolphins can be found off California during colder months, their distribution shifts north towards Oregon and Washington as water temperatures increase during late spring and summer. Their year-round higher densities in the colder waters of northern California, and seasonal abundance in Southern California, overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. Some of Anti-Submarine Warfare activities use hull-mounted high duty cycle sonars that increase the potential for auditory effects and masking. Impacts from air guns and explosives would be limited, although a single mortality from explosive activities is predicted.

On average, individuals in the California, Oregon, and Washington stock would be impacted less than once per year. A small number of auditory and non-auditory injuries could occur to individuals, although the average individual risk of injury is negligible. The risk of a mortality is low (less than one) in any year for this stock, but a single mortality are shown in the maximum year of testing impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation, as rough-toothed dolphins are moderately sightable.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and a medium pace of life, northern right whale dolphins have some resilience to missed foraging opportunities due to acoustic disturbance, except for during lactation. Because the California, Oregon, and Washington stock is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. The population trend for this stock is unknown, and because of their longer generation times, this population would require more time to recover if it was further significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. The risk of mortality is extremely unlikely. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock of northern right whale dolphins are unlikely.

Table 2.4-57: Estimated Effects to the California, Oregon, and Washington Stock of Northern Right Whale Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	2	4	(1)	(1)	0
Explosive	Navy Testing	9	9	3	1	(1)
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	15,672	19,635	13	-	-
Sonar	Navy Testing	7,934	1,997	2	-	-
Sonar	USCG Training	249	2	-	-	-
Maximum Annual Total		**23,867**	**21,647**	**19**	**2**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
68,935	0.66	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	6%	4%	16%
Cold	30%	20%	25%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	39%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Acoustic and Oceanographic Research (ONR)	Navy Testing	7%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.20 Common Bottlenose Dolphin (*Tursiops truncatus*)

Bottlenose dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. There are seven stocks in the Study Area – the California coastal stock, the California, Oregon, and Washington Offshore stock, the Hawaii Pelagic stock, the Kauai Niihau stock, the Oahu stock, the 4-Islands stock, and the Hawaii Island stock. Model-predicted impacts are presented in Table 2.4-58 through Table 2.4-64. After the two California stock tables, the five Hawaii stock tables are listed.

Bottlenose dolphins occur in coastal and continental shelf waters of tropical and temperate regions of the Pacific Ocean. The California, Oregon, and Washington Offshore stock of bottlenose dolphins generally congregate at distances greater than 1.9 miles from the coast and throughout the waters of Southern California and Baja California, Mexico. Most impacts on the California, Oregon, and Washington Offshore Stock are due to Anti-Submarine Warfare activities in Southern California. Impacts from explosives and air guns would be limited.

The California coastal stock of bottlenose dolphins can be found up to 1 km from the coast primarily from Monterey, California to Ensenada, Baja Mexico, and typically congregates within 500 m of shore in Southern California. While this stock typically stays nearshore, individuals are highly mobile and this nomadic population travels widely within their range. Their year-round higher densities in warm coastal waters of Southern California overlaps areas where unmanned systems are tested. Most sonar impacts on this stock are due to these activities. These activities may employ lower source levels, but for longer periods and at frequencies where HF cetaceans are susceptible to auditory impacts. A small number of auditory and non-auditory injuries are predicted from explosive activities. There would be no impacts due to air guns.

The potential for an individual to be repeatedly impacted by sonar or explosives is low for either of these wide-ranging, nomadic stocks of bottlenose dolphins in California, and even less so for the large California, Oregon, and Washington stock. On average, individuals in the California, Oregon, and Washington stock would be impacted less than once per year, and individuals in the California Coastal stock could be impacted a few times per year. The average risk of injurious impacts on individuals is negligible for either stock. A small number of auditory and non-auditory injuries could occur to individuals in California, although the risk of a non-auditory injury from this activity is low (less than one) in any year for either stock. A non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injuries may be reduced through visual observation mitigation, as bottlenose dolphins tend to travel in groups of several animals to over a hundred.

Five common bottlenose dolphin stocks occur in both shallow coastal waters and deep offshore waters throughout the Hawaiian Islands, especially throughout the main islands and from the Island of Hawaii to Kure Atoll. Five year-round small and resident population BIAs have been delineated in the main Hawaiian Islands for the populations of common bottlenose dolphins which encompasses the Island of Hawaii (non-hierarchal Island of Hawaii BIA), as well as waters surrounding Niihau to the west and extending east to surround the island of Maui (Kauai Niihau, Oahu, and Maui Nui hierarchal parent BIA). The three hierarchal child BIAs encompass waters around Kauai/Niihau, Oahu, and Maui Nui.

The Oahu stock is residential to nearshore waters around the island of Oahu, where one of the year-round Child BIAs have been delineated for Hawaiian bottlenose dolphins. Most impacts on the Oahu stock of bottlenose dolphins are predicted to occur within the designated small and resident population BIAs, specifically the larger parent BIA and the Kauai Niihau, Oahu, and Maui Nui – Oahu child BIA. Their year-round higher densities in warm coastal waters of Oahu overlaps areas where Submarine Navigation activities would regularly occur along the navigation track into and out of Pearl Harbor. Most sonar impacts on this stock are due to these activities. Impacts due to explosives would be limited, although a single mortality from Obstacle Loading activities is predicted. There would be no impacts due to air guns. On average, individuals in the Oahu stock would be impacted over 60 times per year, although most of these impacts would be behavioral. A small number of auditory and non-auditory injuries could occur to individuals in Oahu, although the average risk of injurious impacts on individuals is negligible. The risk of a non-auditory injury or mortality from this activity is low (less than one) in any year for this stock, but a single non-auditory injury and mortality are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury or mortality may be reduced through visual observation mitigation.

The Maui Nui (formerly the 4-Islands) stock of bottlenose dolphins is residential to nearshore waters around the islands of Maui, Kahoolawe, Lanai, and Molokai, which is near the center of the year-round parent BIA that has been delineated for Hawaiian bottlenose dolphins. Most impacts on the Maui Nui stock of bottlenose dolphins are predicted to occur within the designated small and resident population BIAs, specifically the larger parent BIA and the Kauai Niihau, Oahu, and Maui Nui – Maui Nui child BIA. Their year-round higher densities in warm coastal waters of these four Hawaiian islands overlaps areas where Surface Ship Object Detection activities would occur. Most sonar impacts on this stock are due to these activities. Impacts due to explosives would be limited, and there would be no impacts due to air guns. No injuries are predicted for this stock.

The Kauai Niihau stock of bottlenose dolphins is residential to nearshore waters around the islands of Kauai and Niihau, which does not overlap the BIAs that have been delineated for Hawaiian bottlenose dolphins. Most impacts on the Kauai Niihau stock of bottlenose dolphins are predicted to occur within the designated small and resident population BIAs, specifically the larger parent BIA and to a lesser extent the Kauai Niihau, Oahu, and Maui Nui – Kauai Niihau child BIA. Their year-round higher densities in warm coastal waters of these two Hawaiian islands overlap areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. The number of impacts due to explosives would be limited, and there would be no impacts due to air guns. No injuries are predicted for this stock.

The Hawaii Island stock of bottlenose dolphins is residential to nearshore waters around the islands of Hawaii, where one of the year-round BIAs have been delineated for Hawaiian bottlenose dolphins. Most impacts on the Hawaii Island stock of bottlenose dolphins are predicted to occur within the non-hierarchal Island of Hawaii small and resident population BIA. Their year-round higher densities in the warm coastal waters around the Island of Hawaii overlaps areas where Anti-Submarine Warfare activities would occur. Most sonar impacts on this stock are due to these activities. The number of impacts due to explosives would be limited, and there would be no impacts due to air guns. No injuries are predicted for this stock.

The Hawaii Pelagic stock of bottlenose dolphins is residential to the warm tropical waters around Hawaii. However, this stock has the largest range out of the other bottlenose dolphin stock in the Hawaii portion of the HCTT Study Area, as it extends throughout the Hawaii Range Complex. Submarine Navigation near Pearl Harbor would contribute a large portion of impacts. Impacts due to explosives and air guns would be limited, although a single mortality that is mostly attributable to Obstacle Loading activities is predicted.

On average, individuals in the Maui Nui stock and Kauai Niihau stock could be impacted several times per year, individuals in the Hawaii Pelagic stock would be impacted less than twice per year, and individuals in the Hawaii Island stock could be impacted less than once per year. There are no annual injuries predicted in the Maui Nui stock, Kauai Niihau stock, or the Hawaii Island stock. The average individual risk of injury is negligible in all four stocks, but a small number of injuries and one mortality could occur in the Hawaii Pelagic stock. For the Hawaii Pelagic stock, the risk of mortality is low (less than one) in any year, but a single mortality is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury or mortality may be reduced through visual observation mitigation, as bottlenose dolphins have relatively higher sightability.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Bottlenose dolphins are income breeders with a small-medium body size and a medium pace of life, suggesting they are moderately resilient to foraging disruption due to acoustic disturbance, except for during lactation. Because these stocks are nomadic, the risk of repeated exposures to individuals is likely similar within these populations as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. While the California Coastal stock of bottlenose dolphins has a stable and potentially increasing population, the other bottlenose dolphin stocks in the Hawaii Study Area have unknown population trends. Since this species has longer generation times, they would require more time to recover if significantly impacted.

Several instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who suffer a slight recoverable injury or an auditory injury may experience minor energetic costs. Because bottlenose dolphins are resilient to limited instances of disturbance, long-term consequences are unlikely for any stock in the Study Area.

Table 2.4-58: Estimated Effects to the California, Oregon, and Washington Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	38	40	9	(1)	0
Explosive	Navy Testing	6	7	1	0	-
Explosive	USCG Training	(1)	(1)	-	-	-
Sonar	Navy Training	11,368	5,492	3	-	-
Sonar	Navy Testing	9,699	1,286	(1)	-	-
Sonar	USCG Training	119	-	-	-	-
Maximum Annual Total		**21,232**	**6,826**	**14**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
42,395	0.66	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	High Seas
Warm	59%	5%	1%
Cold	34%	0%	0%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	19%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	14%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	7%
Medium Coordinated Anti-Submarine Warfare	Navy Training	6%
Composite Training Unit Exercise (Strike Group)	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-59: Estimated Effects to the California Coastal Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	9	15	6	(1)	-
Explosive	Navy Testing	-	(1)	0	0	-
Sonar	Navy Training	484	8	-	-	-
Sonar	Navy Testing	811	20	-	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**1,306**	**44**	**6**	**1**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
453	3.00	0.02

Season	Percent of Total Effects	
	SOCAL	PMSR
Warm	39%	1%
Cold	59%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	30%
Surface Ship Object Detection	Navy Training	26%
Unmanned Underwater Vehicle Testing	Navy Testing	22%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-60: Estimated Effects to the Oahu Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	29	21	4	(1)	(1)
Explosive	Navy Testing	-	(1)	0	0	-
Sonar	Navy Training	6,672	67	0	-	-
Sonar	Navy Testing	407	35	(1)	-	-
Maximum Annual Total		**7,108**	**124**	**5**	**1**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
113	64.06	0.06

Season	Percent of Total Effects
	HRC
Warm	46%
Cold	54%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Navigation	Navy Training	58%
Mine Countermeasures - Ship Sonar	Navy Training	20%
Surface Ship Object Detection	Navy Training	14%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Kauai Niihau, Oahu, and Maui Nui - Oahu (All)	7,060	119	4	-	-
S-BIA-P	Kauai Niihau, Oahu, and Maui Nui (All)	7,086	121	4	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-61: Estimated Effects to the Maui Nui Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	0	1	-	-	-
Explosive	Navy Testing	2	2	-	-	-
Sonar	Navy Training	186	2	-	-	-
Sonar	Navy Testing	121	12	0	-	-
Maximum Annual Total		**309**	**17**	**0**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
65	5.02	0.00

Season	Percent of Total Effects: HRC
Warm	50%
Cold	50%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Surface Ship Object Detection	Navy Training	45%
Vehicle Testing	Navy Testing	13%
Anti-Submarine Warfare Tracking Test (Rotary Wing)	Navy Testing	8%
Submarine Navigation	Navy Training	7%
Anti-Submarine Warfare Torpedo Test (Aircraft)	Navy Testing	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Kauai Niihau, Oahu, and Maui Nui - Maui Nui (All)	291	16	-	-	-
S-BIA-P	Kauai Niihau, Oahu, and Maui Nui (All)	307	17	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-62: Estimated Effects to the Hawaii Island Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	0	(1)	-	-	-
Sonar	Navy Training	2	3	-	-	-
Sonar	Navy Testing	3	-	-	-	-
Maximum Annual Total		**5**	**4**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
138	0.07	0.00

Season	Percent of Total Effects HRC
Warm	20%
Cold	80%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	34%
Vehicle Testing	Navy Testing	27%
Unmanned Underwater Vehicle Training - Certification and Development	Navy Training	11%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	9%
Acoustic and Oceanographic Research (ONR)	Navy Testing	6%
Gunnery Exercise Surface-to-Surface Ship Medium-Caliber	Navy Training	6%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Hawaii Island (All)	4	3	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-63: Estimated Effects to the Hawaii Pelagic Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	134	114	14	1	(1)
Explosive	Navy Testing	51	32	4	1	-
Explosive	Army Training	2	1	(1)	0	-
Sonar	Navy Training	32,258	5,040	3	-	-
Sonar	Navy Testing	4,805	842	1	-	-
Sonar	USCG Training	33	-	-	-	-
Maximum Annual Total		**37,284**	**6,029**	**23**	**2**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
25,120	1.73	0.00

Season	Percent of Total Effects HRC
Warm	47%
Cold	52%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Navigation	Navy Training	27%
Surface Ship Object Detection	Navy Training	21%
Mine Countermeasures - Ship Sonar	Navy Training	9%
Medium Coordinated Anti-Submarine Warfare	Navy Training	7%
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	6%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-64: Estimated Effects to the Kauai and Niihau Stock of Bottlenose Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	-	(1)	0	0	-
Explosive	Navy Testing	0	0	0	-	-
Sonar	Navy Training	945	233	-	-	-
Sonar	Navy Testing	276	5	-	-	-
Maximum Annual Total		**1,221**	**239**	**0**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
113	12.92	0.00

Season	Percent of Total Effects HRC
Warm	41%
Cold	59%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	35%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	32%
Anti-Submarine Warfare Torpedo Exercise - Maritime Patrol Aircraft	Navy Training	11%
Undersea Range System Test	Navy Testing	10%
Long Range Acoustic Communications	Navy Testing	7%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA-C	Kauai Niihau, Oahu, and Maui Nui - Kauai Niihau (All)	969	184	0	-	-
S-BIA-P	Kauai Niihau, Oahu, and Maui Nui (All)	1,202	239	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
version.20241107

2.4.2.21 Short-Beaked Common Dolphin (*Delphinus delphis*)

Short-beaked common dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. One short-beaked common dolphin stock is in the Study Area – the California, Oregon, and Washington stock. Model-predicted impacts are presented in Table 2.4-65.

Short-beaked common dolphins exhibit substantial seasonal and annual variability due to changes in oceanographic conditions, resulting in shifts both north-south and inshore-offshore. The California, Oregon, and Washington stock of short-beaked common dolphins has a widespread distribution off California. They generally congregate in the California portion of the HCTT Study Area throughout the year, distributed between the coast and at least 345 miles from shore. Their higher densities in nearshore waters of Baja California, Mexico and offshore waters of Southern California overlap areas where Anti-Submarine Warfare activities would occur. While most auditory injuries would be due to Acoustic and Oceanographic Research activities, most impacts overall to this stock are due to Anti-Submarine Warfare activities. Some of Anti-Submarine Warfare activities use hull-mounted high duty cycle sonars that increase the potential for auditory effects and masking. Impacts from explosives would occur from a variety of activities, including Ship Shock Trials, Mine Neutralization Explosive Ordnance Disposal, Underwater Demolition, and Amphibious Breaching activities. Impacts from air guns would be limited.

Most of the model-predicted mortalities and some of the non-auditory and auditory injuries for testing explosives are due to Small Ship Shock Trials. Most of the model-predicted mortalities, non-auditory and auditory injuries for training explosives are due to Mine Neutralization Explosive Ordnance Disposal, Amphibious Breaching, and other Mine Warfare activities. The mortalities, non-auditory injuries, and auditory injuries associated with these activities could be mitigated, as the Navy conducts mitigation in the form of pre-event visual observations for these specific training activities (see the *Mitigation* section). Navy conducts much more extensive visual observations for Ship Shock Trials in accordance with NMFS-reviewed event-specific mitigation and monitoring plans (see the *Mitigation* section). Adherence to these plans increases the likelihood that Lookouts would sight surface-active marine mammals within the explosive activity's mitigation zone, particularly species that occur in groups. Short-beaked common dolphins tend to travel in large groups averaging hundreds, and occasionally thousands, of individuals. No marine mammal mortalities have been identified during multi-day post-event observations following previous Ship Shock Trials.

On average, individuals in this stock would be impacted a couple times per year. Some injuries and mortalities could occur to individuals in the California, Oregon, and Washington stock, although the average individual risk of injury is negligible. In addition, the risk of a single auditory injury from U.S. Coast Guard explosives is low (less than one) in any year for this stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury and mortality may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and a medium pace of life, short-beaked dolphins have some resilience to missed foraging opportunities due to acoustic disturbance, except for during lactation. Because this stock is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. The population trend for the California, Oregon, and Washington stock of short-beaked common dolphins is unknown. However, there seems to be a recent increase in the population within the HCTT Study Area which is likely due to distribution shifts north from Mexico. Due to this species' longer generation times, this population would require more time to recover if significantly impacted.

A few instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an injury may experience minor energetic costs. Long-term consequences to the stock are unlikely.

Table 2.4-65: Estimated Effects to the California, Oregon, and Washington Stock of Short-Beaked Common Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	17	-	-	-	-
Explosive	Navy Training	1,413	1,078	255	50	13
Explosive	Navy Testing	428	492	103	21	5
Explosive	USCG Training	3	2	(1)	-	-
Sonar	Navy Training	876,990	548,702	389	-	-
Sonar	Navy Testing	611,376	119,400	58	-	-
Sonar	USCG Training	9,634	19	-	-	-
Maximum Annual Total		**1,499,861**	**669,693**	**806**	**71**	**18**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,056,308	2.05	0.00

Season	Percent of Total Effects			
	SOCAL	PMSR	NOCAL	High Seas
Warm	44%	6%	2%	1%
Cold	38%	4%	1%	3%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	21%
Medium Coordinated Anti-Submarine Warfare	Navy Training	10%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	9%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	6%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.22 Long-Beaked Common Dolphin (*Delphinus capensis*)

Long-beaked common dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. One long-beaked common dolphin stock is in the Study Area – the California stock. Model-predicted impacts are presented in Table 2.4-66.

The California stock of long-beaked common dolphins generally have higher abundances nearshore in Southern California year-round, although Southern California waters represent the northern limit to this species' range. The seasonal and inter-annual changes in abundance off California are assumed to reflect the shifts in the movements of long-beaked common dolphins between U.S. and Mexican waters. Impacts would be slightly higher in the warm season when they have higher densities in Southern California. Their higher densities in nearshore waters in Southern California overlap areas where Unmanned Underwater Vehicle Testing would occur. Most impacts would be due to this sonar activity, which may employ lower source levels, but for longer periods and at frequencies where HF cetaceans are susceptible to auditory impacts. Impacts from explosives would occur from a variety of activities, including Ship Shock Trials, EOD Mine Neutralization, Underwater Demolition, and Amphibious Breaching activities. Impacts from air guns would be limited.

The model-predicted mortality and some of the injuries for testing explosives are due to Small Ship Shock Trials. The mortality and injuries associated with this activity could be mitigated, as the Navy conducts extensive visual observations for Ship Shock Trials in accordance with NMFS-reviewed event-specific mitigation and monitoring plans (see the *Mitigation* section). Training explosive activities (e.g., EOD Mine Neutralization, Amphibious Breaching activities) are also predicted to result in a few mortalities but have specific on-site mitigations, including visual observations, that may reduce the number of impacts on marine mammals in the area (see the *Mitigation* section for details). Adherence to these plans increases the likelihood that Lookouts would sight surface-active marine mammals within the explosive activity's mitigation zone, particularly species that occur in groups. Long-beaked common dolphins tend to travel in large groups of up to 500 individuals. No marine mammal mortalities have been identified during multi-day post-event observations following previous Ship Shock Trials.

On average, individuals in this stock would be impacted less than twice per year. A small number of injuries and mortalities could occur to individuals in the California stock, although the average individual risk of injury is negligible. The risk of injury and mortality may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small body and a medium pace of life, long-beaked common dolphins have some resilience to missed foraging opportunities due to acoustic disturbance, except for during lactation. Because this stock is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. The population trend for the California stock of long-beaked common dolphins is unknown. However, there seems to be a recent increase in the population within the HCTT Study Area which is likely due to distribution shifts north from Mexico. Due to this species' longer generation times, this population would require more time to recover if significantly impacted.

A few instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an injury may experience minor energetic costs. A few mortalities are anticipated but long-term consequences to the stock are unlikely.

Table 2.4-66: Estimated Effects to the California Stock of Long-Beaked Common Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	3	-	-	-	-
Explosive	Navy Training	273	306	75	18	3
Explosive	Navy Testing	72	83	27	6	1
Explosive	USCG Training	(1)	(1)	0	-	-
Sonar	Navy Training	70,884	30,889	20	-	-
Sonar	Navy Testing	181,795	11,646	6	-	-
Sonar	USCG Training	924	1	-	-	-
Maximum Annual Total		**253,952**	**42,926**	**128**	**24**	**4**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
209,100	1.42	0.00

Season	Percent of Total Effects	
	SOCAL	PMSR
Warm	45%	9%
Cold	37%	8%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Unmanned Underwater Vehicle Testing	Navy Testing	31%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	19%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	8%
Medium Coordinated Anti-Submarine Warfare	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.23 Risso's Dolphin (*Grampus griseus*)

Risso's dolphins are in the HF cetacean auditory group and the Odontocete behavioral group. Two Risso's dolphin stocks are in the Study Area – the California, Oregon, and Washington stock and the Hawaii stock. Model-predicted impacts are presented in Table 2.4-67 and Table 2.4-68.

The California, Oregon, and Washington stock of Risso's dolphins can be found year-round in Southern California but is more abundant in the area during the cold-water months, consistent with their seasonal shifts north to Oregon and Washington waters during warmer months. While they are commonly seen over the slope and in offshore waters, they also frequent coastal waters around islands in Southern California. Their higher densities in Southern California, especially in winter and spring, overlap areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts are behavioral responses. The number of impacts due to explosives and air guns would be limited.

The Hawaii stock of Risso's dolphins have the highest densities offshore of the Hawaiian Islands in waters approximately 2,500 m to 4,500 m depth, and mid-range densities farther offshore. This stock would be relatively less impacted, with very few predicted injuries. Most impacts on this stock are due to Anti-Submarine Warfare activities. The number of impacts due to explosives would be limited. There would be no impacts due to air guns.

On average, individuals in the California, Oregon, and Washington stock would be impacted a couple times per year. On average, individuals in the Hawaii stock would be impacted less than once per year. The average risk of injury is negligible, although a few non-auditory injuries could occur to individuals in California and a small number of auditory injuries could occur to individuals in either stock. The risk of any auditory injury is low (less than one) in any year for the Hawaii stock, but a couple injuries are shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of injury may be reduced through visual observation mitigation, as Risso's dolphins are relatively sightable.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As income breeders with a small-medium body and a medium pace of life, Risso's dolphins are moderately resilient to foraging disruption due to acoustic disturbance, except for during lactation. Because both stocks in the HCTT Study Area are nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. Both stocks have unknown population trends. Due to this species' longer generation times, this population would require more time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock and Hawaii stock of Risso's dolphins are unlikely.

Table 2.4-67: Estimated Effects to the California, Oregon, and Washington Stock of Risso's Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	-	-	-	-
Explosive	Navy Training	23	38	9	3	-
Explosive	Navy Testing	11	10	4	(1)	0
Explosive	USCG Training	0	(1)	-	-	-
Sonar	Navy Training	17,117	7,907	3	-	-
Sonar	Navy Testing	15,852	2,686	1	-	-
Sonar	USCG Training	187	-	-	-	-
Maximum Annual Total		**33,191**	**10,642**	**17**	**4**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
19,357	2.27	0.00

	Percent of Total Effects			
Season	**SOCAL**	**PMSR**	**NOCAL**	**High Seas**
Warm	39%	4%	2%	1%
Cold	48%	5%	1%	0%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	17%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	13%
Medium Coordinated Anti-Submarine Warfare	Navy Training	8%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	7%
Undersea Warfare Testing	Navy Testing	7%
At-Sea Sonar Testing	Navy Testing	6%
Unmanned Underwater Vehicle Testing	Navy Testing	6%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-68: Estimated Effects to the Hawaii Stock of Risso's Dolphins over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	2	2	0	0	-
Explosive	Navy Testing	(1)	(1)	(1)	-	-
Explosive	Army Training	-	-	(1)	0	-
Sonar	Navy Training	2,781	2,595	(1)	-	-
Sonar	Navy Testing	745	396	(1)	-	-
Sonar	USCG Training	35	-	-	-	-
Maximum Annual Total		**3,564**	**2,994**	**4**	**0**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
8,649	0.76	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	47%	3%
Cold	48%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	33%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	12%
Submarine Sonar Maintenance and Systems Checks	Navy Training	12%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.24 Dall's Porpoise (*Phocoenoides dalli*)

Dall's porpoises are in the VHF cetacean auditory group and the Odontocete behavioral group. The California, Oregon, and Washington stock is the only stock in the Study Area. Model-predicted impacts are presented in Table 2.4-69.

The California, Oregon, and Washington stock of Dall's porpoises can be found from Baja California, Mexico to the northern Bering Sea. They shift their distribution southward during cooler-water periods on both interannual and seasonal time scales. They primarily congregate in shelf and slope waters, and decrease substantially in waters warmer than 63°F. Their higher densities in Southern California during the cold season overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities.

As VHF cetaceans, Dall's porpoises are more susceptible to auditory impacts in mid- to high frequencies than other species. Auditory impacts from sonars are attributable to a variety of activities, with most auditory injuries attributable to Anti-Submarine Warfare activities. As VHF cetaceans, Dall's porpoises are also more susceptible than other species to auditory impacts from explosives. Auditory injuries are attributable to a variety of activities. Most auditory injuries due to explosives are attributable to Missile and Rocket testing activities and Air-to-Surface Missile activities in PMSR, and EOD Mine Neutralization activities in Southern California. The number of impacts due to air guns would be limited.

On average, individuals in this stock would be impacted about once per year. The average risk of injury is negligible, although auditory and non-auditory injuries are predicted. The risk of a single auditory injury from U.S. Coast Guard explosives is low (less than one) in any year for this stock, but a auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Similarly, the risk of a single non-auditory injury from Navy training explosives is low (less than one) in any year for this stock, but a non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed above. The risk of auditory or non-auditory injury may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small odontocetes and income breeders with a fast pace of life, Dall's porpoises are less resilient to missed foraging opportunities than larger odontocetes. Because the California, Oregon, and Washington stock of Dall's porpoise is nomadic, the risk of repeated exposures to individuals is likely similar within the population as animals move throughout their range. Risk of impacts would also be similar across seasons and critical life functions. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations are quick to recover. Additionally, this stock of Dall's porpoise is unknown but likely stable.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California, Oregon, and Washington stock of Dall's porpoise are unlikely.

Table 2.4-69: Estimated Effects to the California, Oregon, and Washington Stock of Dall's Porpoise over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	9	8	1	-	-
Explosive	Navy Training	155	433	185	(1)	-
Explosive	Navy Testing	438	631	304	1	0
Explosive	USCG Training	2	2	(1)	-	-
Sonar	Navy Training	6,430	36,826	522	-	-
Sonar	Navy Testing	6,191	8,086	222	-	-
Sonar	USCG Training	169	239	-	-	-
Maximum Annual Total		**13,394**	**46,225**	**1,235**	**2**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
61,840	0.98	0.02

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	7%	2%	8%
Cold	41%	26%	15%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	29%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	16%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	6%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	5%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.2.25 Harbor Porpoise (*Phocoena phocoena*)

Harbor porpoises are in the VHF cetacean auditory group and the Sensitive behavioral group. Four harbor porpoise stocks are in the Study Area – the Northern California/Southern Oregon stock, the San Francisco Russian River stock, the Monterey Bay stock, and the Morro Bay stock. Model-predicted impacts on the Northern California/Southern Oregon stock, the San Francisco Russian River stock, the Monterey Bay stock, and the Morro Bay stock are presented in Table 2.4-70 through Table 2.4-73.

Harbor porpoises generally have higher abundances in shallow waters (less than 200 m) and near shore, but they sometimes move into deeper offshore waters. However, this species has no overlap with nearshore or offshore areas in the SOCAL Range Complex (e.g., San Diego, SOAR) or the southern nearshore portions of PMSR (e.g., Port Hueneme).

The Northern California/Southern Oregon stock of harbor porpoises congregates in shallow coastal waters of northern California and southern Oregon, occasionally moving offshore. Their higher densities in northern California during the cold season overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. All impacts on this stock are behavioral. Impacts from explosives are negligible, and no impacts are predicted due to air guns.

The Monterey Bay stock of harbor porpoises generally congregate in shallow coastal waters near Monterey Bay, California. A non-hierarchical small and resident population BIA for the Monterey Bay stock of harbor porpoise off California encompasses waters from land to the 200-meter isobath within the defined range. The abundance of individuals in this stock increased after when gillnet bycatch was reduced in their habitat. Harbor porpoise behavior may be impacted within the designated Monterey Bay BIA. Their higher densities in northern California during the cold season overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. All impacts on this stock are behavioral. Impacts from explosives are negligible, and no impacts are predicted due to air guns.

The San Francisco Russian River stock of harbor porpoises generally congregate in shallow coastal waters near San Francisco, California. Their higher densities in northern California during the cold season overlaps areas where Anti-Submarine Warfare activities would occur. Most impacts on this stock are due to these activities. Most impacts on this stock are behavioral. Impacts from explosives and air guns are limited. However, most auditory injuries for this stock of harbor porpoises would be due to Submarine and Unmanned Underwater Vehicle Subsea and Seabed Explosive activities.

The Morro Bay stock of harbor porpoises generally congregate in shallow coastal waters near Morro Bay in central California. A non-hierarchical small and resident population BIA for the Morro Bay stock of harbor porpoise off California encompasses waters from land to the 200-meter isobath within the defined range. The abundance of individuals in this stock increased after when gillnet bycatch was reduced in their habitat. Most of the impacts on the Morro Bay stock of harbor porpoises are predicted to occur within the Morro Bay BIA. Their higher densities in central California during the cold season overlaps areas where Submarine Mobile Mine activities and Anti-Submarine Warfare activities would occur on PMSR. Most impacts on this stock are due to these activities. Most predicted auditory injuries from explosives would occur from Air-to-Surface and Surface-to-Air Missile Testing activities. There are no impacts predicted due to air guns.

As VHF cetaceans, harbor porpoises are more susceptible to auditory impacts in mid- to high frequencies compared to other species. Auditory impacts from sonars are attributable to a variety of activities, with most behavioral impacts attributable to Anti-Submarine Warfare activities. Harbor porpoises are more susceptible to behavioral disturbance than other species. Harbor porpoises are highly sensitive to many sound sources and generally demonstrate strong avoidance of most types of acoustic stressors.

As VHF cetaceans, harbor porpoises are also more susceptible than other species to auditory impacts from explosives. Auditory injuries are attributable to a variety of activities, with most auditory injuries attributable to explosive activities. Most training auditory injuries are associated with submarine and UUV subsea and seabed warfare activities in the NOCAL Range Complex. Most testing auditory injuries area associated with Air-to-Surface and Surface-to-Air Missile Testing activities in PMSR.

On average, individuals in the San Francisco Russian River stock and the Morro Bay stock would be impacted about once per year. On average, individuals in the Northern California/Southern Oregon stock and the Monterey Bay stock would be impacted less than once per year. The average risk of injury is negligible for all four stocks, although injuries are predicted for the San Francisco Russian River stock and the Morro Bay stock. The risk of a single auditory injury from air guns is low (less than one) in any year for San Francisco Russian River stock, but an auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Similarly, the risk of a single non-auditory injury from explosive testing is low (less than one) in any year for the Morro Bay stock, but a non-auditory injury is shown in the maximum year of impacts due to summing risk across seven years and following the rounding approach discussed above. The risk of auditory or non-auditory injury may be reduced through visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. As small odontocetes and income breeders with a fast pace of life, harbor porpoises are less resilient to missed foraging opportunities than larger odontocetes. Because all four stocks of harbor porpoise on the U.S. west coast portion of the Study Area are residential, the risk of repeated exposure would be higher for stocks that have high site fidelity in locations that overlap with the Proposed Action. However, most of these stocks inhabit coastal near-shore areas with minimal geographical overlap with the Proposed Action. Additionally, the populations of harbor porpoises in Morro Bay and Monterey Bay are likely increasing, and the Northern California/Southern Oregon and the San Francisco Russian River stocks of harbor porpoises are relatively stable. Although reproduction in populations with a fast pace of life are more sensitive to foraging disruption, these populations are quick to recover.

The limited instances of predicted behavioral and non-injurious auditory impacts are unlikely to result in any long-term impacts on individuals, although individuals who suffer an auditory injury in the San Francisco Russian River may experience minor energetic costs. Long-term consequences to the stock are unlikely.

Table 2.4-70: Estimated Effects to the Northern California/Southern Oregon Stock of Harbor Porpoise over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Sonar	Navy Training	357	0	-	-	-
Sonar	Navy Testing	124	-	-	-	-
Maximum Annual Total		**481**	**0**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
15,303	0.03	0.00

Season	Percent of Total Effects
	NOCAL
Warm	32%
Cold	68%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	62%
Acoustic and Oceanographic Research (ONR)	Navy Testing	26%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-71: Estimated Effects to the Monterey Bay Stock of Harbor Porpoise over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Testing	0	-	-	-	-
Sonar	Navy Training	1,314	0	-	-	-
Sonar	Navy Testing	865	-	-	-	-
Maximum Annual Total		**2,179**	**0**	**-**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
4,530	0.48	0.00

Season	Percent of Total Effects
	NOCAL
Warm	29%
Cold	71%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	49%
Acoustic and Oceanographic Research (ONR)	Navy Testing	40%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Monterey Bay (All)	1,178	-	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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Table 2.4-72: Estimated Effects to the San Francisco Russian River Stock of Harbor Porpoise over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	2	(1)	-	-
Explosive	Navy Training	-	22	24	-	-
Explosive	Navy Testing	3	3	1	-	-
Explosive	USCG Training	0	0	0	-	-
Sonar	Navy Training	6,869	29	0	-	-
Sonar	Navy Testing	3,023	6	0	-	-
Sonar	USCG Training	2	-	-	-	-
Maximum Annual Total		**9,898**	**62**	**26**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
9,974	1.00	0.00

Season	Percent of Total Effects
	NOCAL
Warm	39%
Cold	61%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	52%
Acoustic and Oceanographic Research (ONR)	Navy Testing	30%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-73: Estimated Effects to the Morro Bay Stock of Harbor Porpoise over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	-	13	11	0	-
Explosive	Navy Testing	74	159	75	(1)	0
Sonar	Navy Training	3,824	46	0	-	-
Sonar	Navy Testing	254	3	(1)	-	-
Maximum Annual Total		**4,152**	**221**	**87**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
4,191	1.06	0.02

Season	Percent of Total Effects	
	PMSR	NOCAL
Warm	26%	0%
Cold	73%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Submarine Mobile Mine and Mine Laying Exercise	Navy Training	46%
Medium Coordinated Anti-Submarine Warfare	Navy Training	20%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	13%
Acoustic and Oceanographic Research (ONR)	Navy Testing	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
S-BIA	Morro Bay (All)	3,815	186	73	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.3 Impacts on Pinnipeds

The pinnipeds analyzed below are either in the Phocid Carnivores in Water (PCW) or the Otariids and other non-phocid marine carnivores in Water (OCW) auditory groups. The updated PCW criteria reflect greater susceptibility to auditory effects at low and mid-frequencies than previously analyzed. The updated OCW criteria reflects substantially greater susceptibility to auditory effects across their hearing range compared to previous analyses (Figure 2.2-1). For sonar exposures, the updated Pinniped in-water behavioral response function indicates greater sensitivity to behavioral disturbance compared to the prior analysis. As described in Section 2.2.2 (Quantifying Impacts on Hearing), the methods to model avoidance of sonars have been revised to base a species' probability of an avoidance responses on the behavioral response function. In addition, the cut-off conditions for predicting significant behavioral responses have been revised as shown in Section 2.2.3 (Quantifying Behavioral Responses to Sonars). These factors interact in complex ways that the results of this analysis challenging to compare to prior analyses. Overall impacts due to sonar have increased for pinnipeds compared to the prior analysis, which is primarily due to the changes in auditory and behavioral criteria mentioned above, and changes to species densities (see the *Density TR*). There has also been an increase in hull-mounted sonar use (see Section 2.1.1 Impacts from Sonars and Other Transducers)

Some species of pinnipeds would be exposed to pile driving activities conducted within Port Hueneme, as detailed in Section 2.1.3 (Impacts from Pile Driving). Impacts from pile driving are estimated as if all affects would occur underwater, which is conservative as pinnipeds spend a substantial portion of time hauled out on land or with their heads out of the water. Furthermore, the quantitative analysis of pile driving did not account for avoidance. Estimated ranges to effect are shown in Section 2.5.3 (Ranges to Effects for Pile Driving).

Impacts on pinnipeds due to land-based launches at San Nicolas Island in PMSR and at the PMRF on Kauai in the Hawaii Study Area were analyzed separately from the impacts due to activities conducted within and over the sea space of the Study Area analyzed here.

Impacts due to non-modeled acoustic stressors are discussed above in Section 2.1.4 (Impacts from Vessel Noise), Section 2.1.5 (Impacts from Aircraft Noise), and Section 2.1.6 (Impacts from Weapons Noise).

2.4.3.1 Hawaiian Monk Seal (*Neomonachus schauinslandi*)*

The only stock of Hawaiian monk seals in the Study Area is the Hawaiian stock which is endangered throughout its range. Hawaiian monk seals are in the PCW hearing group and Pinniped behavioral group. Model-predicted impacts are presented in Table 2.4-74. Although Hawaiian monk seals are analyzed using the same criteria and thresholds as other pinnipeds, the best available scientific information suggests that their hearing is less sensitive than other pinnipeds (Ruscher et al., 2021; Sills et al., 2021). Therefore, the quantitative analysis presented below is likely to be conservative.

Hawaiian monk seals are residents of the main Hawaiian Islands and Northwest Hawaiian Islands where they breed, but sightings have been reported south of the Hawaiian island chain. They mostly inhabit nearshore or shallow water but have been observed traveling between islands, atolls, and submerged reefs, and even on occasion making pelagic foraging trips. Hawaiian monk seals are generally solitary, and while some individuals adhere to a single island, others regularly travel between islands within their range year-round.

Most auditory impacts would be attributable to sonar used in Anti-Submarine Warfare activities. It is more likely that Hawaiian monk seals would experience short-term behavioral impacts, which are mostly attributable to Anti-Submarine Warfare and Surface Ship Object Detection activities. The average risk of injurious impacts per individual is negligible although four AINJ and one non-auditory injury is predicted. The single predicted non-auditory injury due to explosives during Mine Warfare and Expeditionary Warfare (Obstacle Loading) conducted at Puuloa Underwater Range and is a result of summing risk across seven years and following the approach discussed in Section 2.4 (Species Impact Assessments). The pre-event activity-based mitigation prescribed for these activities in the *Mitigation* may reduce the potential for injurious impacts. No effects are predicted from noise produced by air guns, which may be used in testing activities at least 3 NM from shore in the Hawaii Range Complex. No effects are possible from pile driving because there is no geographic overlap of this stressor.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Hawaiian monk seals have a fast pace of life and capital breeding strategy which makes them more resilient to short-term foraging disruptions. Their primary habitat in the Northwestern Hawaiian Islands is within the Hawaii Study Area, and their main Hawaiian Islands habitat is within the Hawaii Range Complex. Because Hawaiian monk seals are residential, and the population is located entirely within the Hawaii Study Area, the risk of repeated exposure is higher for this species compared to other pinnipeds with nomadic or migratory movement ecology.

Although Hawaiian monk seals are endangered and depleted, they have a stable and possibly increasing population trend. The greatest threats to the species include reduced prey availability, shark predation, anthropogenic disturbance, and loss of habitat due to climate change. One to a few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the Hawaiian stock of Hawaiian monk seals are unlikely.

Based on the analysis presented above, vessel, aircraft, and weapons noise produced during training activities <u>may affect, but are not likely to adversely affect,</u> Hawaiian monk seals. The use of sonar and explosives during training activities <u>may affect, and are likely to adversely affect,</u> Hawaiian monk seals. Activities that involve the use of pile driving are <u>not applicable</u> to Hawaiian monk seals because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, air guns and activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> Hawaiian monk seals. The use of sonar and explosives during testing activities <u>may affect, and are likely to adversely affect,</u> Hawaiian monk seals. Pile diving activities are not conducted during testing.

<u>Critical Habitat</u>

Critical habitat for the Hawaiian monk seal is designated in much of the coastal areas of the Hawaiian Islands (National Oceanic and Atmospheric Administration, 2015). A map of this critical habitat is in *Biological Resources Supplemental Information*. Hawaiian monk seal critical habitat is located entirely within the Hawaii Study Area. A portion of the critical habitat is located within the Hawaii Range Complex and sound from sonar used during anti-submarine warfare, mine countermeasures, and surface ship object detection activities may occur. There are also military readiness activities involving explosives, air guns, aircraft, weapons, and vessel noise for which sound or energy might overlap this designated critical habitat. The essential features of designated critical habitat are: (1) Terrestrial areas and adjacent shallow, sheltered aquatic areas with characteristics preferred by monk seals for pupping and nursing; (2) Marine areas from 0 to 200 m in depth that support adequate prey quality and quantity for juvenile and adult monk seal foraging; and 3) Significant areas used by monk seals for hauling out, resting, or molting. These features are primarily geographical and would not be altered by sound or sound energy from military readiness activities. Terrestrial areas preferred by monk seals for pupping and hauling out have been identified from over 30 years of data (National Oceanic and Atmospheric Administration, 2015).

The biological feature of adequate prey quality and quantity may be affected by the Proposed Action. Hawaiian monk seals prey on fishes and invertebrates in shallow water. Air guns would be used at least 3 NM from shore in the Hawaii Range Complex. Sound from air guns would have no plausible route of effect for impacts on prey quality or quantity within the 200 m depth contour, as ranges to injury or mortality for fishes would be within five meters for this source (see *Impacts on Fishes from Acoustic and Explosive Stressors*). Any sound from air guns would likely not be detectable above ambient noise at distances of a few hundred meters or more. The use of explosives could affect prey quality or quantity in Hawaiian monk seal critical habitat. Most activities involving in-water and surface explosives are conducted more than 12 NM from shore, beyond monk seal critical habitat. Ranges to injury and mortality of fishes due to explosives are on the order of hundreds of meters for the largest explosives (Table 4.4-5), so it is unlikely that sound or energy from explosives would be sufficient to affect prey in designated critical habitat. Explosives close to shore would be used in areas described in Appendix A (Activity Descriptions) and Appendix H (Description of Systems and Ranges). Most of these areas were excluded from the critical habitat designation[7]. Non-impulsive sound sources, such as sonars, have not been known to cause direct injury or mortality to fish under conditions that would be found in the wild (Halvorsen et al., 2012a; Kane et al., 2010; Popper et al., 2007) and would only be expected to result in behavioral reactions or potential masking in fishes and marine invertebrates. Most sonar sources proposed for use during training and testing activities overlapping or adjacent to critical habitat in the Hawaii Study Area would not fall within the frequency range of fish and invertebrate hearing, thereby presenting no plausible route of effect on Hawaiian monk seal prey species. Vessel and aircraft noise may be present in critical habitat but would not cause injury or mortality to fishes or invertebrates and are unlikely to affect prey quality or quantity.

Sonar and activities that produce vessel, aircraft, and weapons noise during training activities would have <u>no effect</u> on designated Hawaiian monk seal critical habitat. The use of explosives during training activities <u>may affect, but is not likely to adversely affect,</u> designated Hawaiian monk seal critical habitat. Activities that involve the use of pile driving are <u>not applicable</u> to designated Hawaiian monk seal critical habitat because there is no geographic overlap of this stressor with critical habitat. Air gun activities are not conducted during training.

[7] These exclusion areas include (1) all areas subject to the Marine Corps Base Hawaii, the Joint Base Pearl Harbor-Hickam, and the Pacific Missile Range Facility Integrated Natural Resource Management Plans; and (2) areas excluded due to national security: the Kingfisher Underwater Training area in marine areas off the northeast coast of Niihau; PMRF Offshore Areas in marine areas off the western coast of Kauai; the Puuloa Underwater Training Range in marine areas outside Pearl Harbor, Oahu; and the Shallow Water Minefield Sonar Training Range off the western coast of Kahoolawe in the Maui Nui area.

Sonar, air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities would have no effect on designated Hawaiian monk seal critical habitat. The use of explosives during testing activities may affect, but is not likely to adversely affect, designated Hawaiian monk seal critical habitat. Pile diving activities are not conducted during testing.

Table 2.4-74: Estimated Effects to the Hawaiian Monk Seal over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	11	16	2	(1)	0
Explosive	Navy Testing	8	9	1	-	-
Explosive	Army Training	(1)	-	-	-	-
Sonar	Navy Training	457	95	0	-	-
Sonar	Navy Testing	58	33	(1)	-	-
Sonar	USCG Training	1	-	-	-	-
Maximum Annual Total		**536**	**153**	**4**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
1,564	0.44	0.00

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	45%	1%
Cold	54%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Surface Ship Object Detection	Navy Training	28%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	13%
Anti-Submarine Warfare Torpedo Exercise - Submarine	Navy Training	9%
Submarine Navigation	Navy Training	8%
Mine Countermeasures - Ship Sonar	Navy Training	5%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	Critical Habitat (All)	356	53	2	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
BIA Types: S - Small/Resident population, M - Migratory, F - Feeding, R - Reproductive, P - Parent, C - Child/Core
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2.4.3.2 Harbor Seal (*Phoca vitulina*)

The only stock of harbor seals in the Study Area is the California stock. Harbor seals are in the PCW hearing group and Pinniped behavioral group. Model-predicted impacts on the California stock are presented in Table 2.4-75.

The California stock of harbor seals is widely distributed along the costal nearshore waters in the California Study Area and PMSR, primarily within 20 km of shore. Harbor seals frequently occupy bays, estuaries, and inlets and prefer waters near haul out locations like the Channel Islands and the mainland coast.

Most auditory impacts would be due to sonar from Intelligence, Surveillance, and Reconnaissance activities in the Southern California Study Area. It is likely that harbor seals would experience short-term behavioral impacts and TTS due to sonar. The majority of predicted AINJ is due to impulsive sources used in Navy training activities including explosives and pile driving. The implementation of pile driving 'soft start' procedures may warn harbor seals to avoid the area, or to haul out, prior to receiving sound levels that could produce these effects. Furthermore, the risk of AINJ or TTS from pile driving may be reduced further through visual observation mitigation. It is more likely that harbor seals may experience short-term behavioral impacts from this activity.

The potential for repeated effects to individuals is low. On average, individuals in this stock would be impacted twice per year. The average risk of injurious impacts on individuals is low although injury could occur. A single mortality is predicted due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). Therefore, the risk of any mortality is unlikely for harbor seals. The risk of injury or mortality could be further reduced with visual observation mitigation.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Harbor seals have a fast pace of life, but pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The California stock of harbor seals is residential, so the risk of repeated effects is likely higher for individuals within the population that inhabit areas overlapping with or adjacent to locations such as Port Hueneme and San Nicholas Island as compared with individuals that reside elsewhere. Because of their shorter generation times, this population would require less time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California stock of harbor seals are unlikely.

Table 2.4-75: Estimated Effects to the California Stock of Harbor Seals over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	1,510	2,050	214	6	1
Explosive	Navy Testing	170	158	14	(1)	0
Explosive	USCG Training	(1)	0	-	-	-
Pile Driving	Navy Training	952	183	20	-	-
Sonar	Navy Training	10,510	1,457	3	-	-
Sonar	Navy Testing	38,391	15,461	3	-	-
Sonar	USCG Training	140	-	-	-	-
Maximum Annual Total		**51,674**	**19,309**	**254**	**7**	**1**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
30,968	2.30	0.01

Season	Percent of Total Effects: SOCAL	Percent of Total Effects: PMSR
Warm	42%	4%
Cold	50%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	55%
Multi-Domain Unmanned Autonomous Systems	Navy Training	9%
Undersea Warfare Testing	Navy Testing	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.3.3 Northern Fur Seal (*Callorhinus ursinus*)

Two Northern fur seal stocks are in the Study Area – the California stock and the Eastern Pacific stock. Fur seals are in the OCW hearing group and the Pinniped behavioral group. Model-predicted impacts on the California stock are presented in Table 2.4-76 and model-predicted impacts on the Eastern Pacific stock are presented in Table 2.4-77.

Northern fur seals are found primarily over the edge of the continental shelf and slope in the north Pacific. The California stock is found on San Miguel Island and a nearby offshore island primarily in summer and up to 40 km to the south of San Miguel Island but may be present there year-round. A small percentage of juvenile and adult female individuals from the Eastern Pacific stock migrate seasonally into the northernmost portion of the Study Area as far south as San Miguel Island.

Most estimated effects for both the California and Eastern Pacific stocks of northern fur seals are behavioral responses due to sonar used in Anti-Submarine Warfare training activities, but TTS is also likely to occur. Although some AINJ is predicted, the overall risk of injurious impacts on individuals is negligible. One non-auditory injury due to explosives is predicted for each stock, however this result is due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). The risk of repeated impacts for the California stock is low, with individuals estimated to be impacted twice per year. The risk of repeated impacts for the Eastern Pacific stock is very low, with individuals estimated to be impacted less than once per year.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Northern fur seals have a fast pace of life, but pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The California stock of northern fur seals is residential, so the risk of repeated impacts on individuals is likely higher for individuals within the population that inhabit areas overlapping with or adjacent to locations in the Study Area. This population of northern fur seals may also be increasing. Although the Eastern Pacific stock of Northern fur seals is depleted and in decline, they are migratory and therefore less susceptible to repeated impacts as they travel seasonally through their range. Northern fur seals have shorter generation times, so these two stocks would require less time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California and Eastern Pacific stocks of northern fur seals are unlikely.

Table 2.4-76: Estimated Effects to the California Stock of Northern Fur Seals over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	(1)	2	(1)	0	-
Explosive	Navy Testing	15	22	6	(1)	0
Explosive	USCG Training	0	0	-	-	-
Sonar	Navy Training	13,512	6,134	2	-	-
Sonar	Navy Testing	1,769	87	0	-	-
Sonar	USCG Training	555	-	-	-	-
Maximum Annual Total		**15,853**	**6,245**	**9**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
14,115	1.57	0.00

Season	Percent of Total Effects: PMSR	Percent of Total Effects: NOCAL
Warm	35%	7%
Cold	36%	22%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	48%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	21%
Acoustic and Oceanographic Research (ONR)	Navy Testing	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 2.4-77: Estimated Effects to the Eastern Pacific Stock of Northern Fur Seals over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	(1)	2	(1)	0	-
Explosive	Navy Testing	19	28	7	(1)	0
Explosive	USCG Training	0	(1)	-	-	-
Sonar	Navy Training	19,371	9,876	2	-	-
Sonar	Navy Testing	3,080	183	(1)	-	-
Sonar	USCG Training	633	-	-	-	-
Maximum Annual Total		**23,105**	**10,090**	**11**	**1**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
626,618	0.05	0.00

Season	Percent of Total Effects: PMSR	Percent of Total Effects: NOCAL
Warm	11%	3%
Cold	42%	44%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	52%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	16%
Acoustic and Oceanographic Research (ONR)	Navy Testing	9%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.3.4 Northern Elephant Seal (*Mirounga angustirostris*)

The only stock of Northern elephant seals in the Study Area is the California breeding stock. However, 80 percent of elephant seals from the breeding population in Mexico migrate into the Study Area seasonally and were included in density estimates that were used to model impacts on this species (see the *Density TR*). Elephant seals are in the PCW hearing group and the Pinniped behavioral group. Model-predicted impacts on the California breeding stock are presented in Table 2.4-78.

The California breeding stock of Northern elephant seals is found in California and is not expected to be present in the Hawaii Study Area. Elephant seals spend approximately 80 percent of their time in the open ocean migrating and foraging, but they can be found in coastal waters seasonally when breeding in their mainland rookeries. Small colonies of northern elephant seals breed and haul-out on Santa Barbara Island, Santa Rosa Island, and San Clemente Island with large colonies on San Nicolas and San Miguel Islands. Northern elephant seals breed on these islands from late December to February and molt primarily from April to July.

Most auditory impacts would be attributable to sonar used in Anti-Submarine Warfare training, UUV testing, Intelligence, Surveillance, and Reconnaissance testing, and other activities. The average risk of injurious impacts on individuals is negligible, although AINJ due to explosives and sonar is predicted. Two non-auditory injuries are predicted to occur as a result of explosives, however this result is due to summing risk across seven years and following the rounding approach discussed in Section 2.4 (Species Impact Assessments). It is more likely that Northern elephant seals would experience TTS and short-term behavioral impacts. The risk of repeated impacts on individuals is low. On average, individuals would experience impacts less than once per year. This risk estimate is conservative because it was calculated using the SAR abundance of 187,386 elephant seals for the California Stock (see Table 2.4-1), however the density used in modeling also accounted for elephant seals from the Mexico population that likely overlap the California stock during migration. The modeling assumes 80 percent of the Mexico population (conservatively estimated at 22,000) may overlap the California stock, for total species abundance of 204,986 in the Study Area.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Despite being the largest species of pinniped in the HCTT Study Area, Northern elephant seals have a fast pace of life. However, pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The California stock of Northern elephant seals spend most of their time at sea, migrating long distances to offshore foraging areas to build up the blubber stores required to support them during breeding and molting haulouts. Therefore, the risk of repeated impacts is likely lower for individuals in this population. Because of their shorter generation times, this population would require less time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California stock of northern elephant seals are unlikely.

Table 2.4-78: Estimated Effects to the California Breeding Stock of Northern Elephant Seals over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	1	-	-	-	-
Explosive	Navy Training	147	229	31	(1)	-
Explosive	Navy Testing	220	332	55	(1)	0
Explosive	USCG Training	2	2	(1)	-	-
Sonar	Navy Training	28,461	39,790	17	-	-
Sonar	Navy Testing	34,434	13,065	5	-	-
Sonar	USCG Training	1,790	(1)	-	-	-
Maximum Annual Total		**65,055**	**53,419**	**109**	**2**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
187,386	0.63	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	27%	8%	5%
Cold	30%	19%	13%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	22%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	12%
Unmanned Underwater Vehicle Testing	Navy Testing	9%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	8%
Acoustic and Oceanographic Research (ONR)	Navy Testing	6%
At-Sea Sonar Testing	Navy Testing	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.3.5 Guadalupe Fur Seal (*Arctocephalus townsendi*)*

The only stock of Guadalupe fur seals in the Study Area is the Mexico stock which is threatened throughout its range. Fur seals are in the OCW hearing group and the Pinniped behavioral group. Model-predicted impacts are presented in Table 2.4-79.

Guadalupe fur seals breed primarily on Guadalupe Island, which is located outside but near the southern edge of the California Study Area. They are found in pelagic waters of the Study Area, but do not typically haul out within the Study Area. They are not found in the Hawaii Study Area. Since the prior analysis, the density of Guadalupe fur seals in the Study Area has substantially increased (see the *Density TR*).

Most auditory impacts would be attributable to sonar used in Navy training and testing activities. Few impacts are predicted outside the SOCAL Range Complex. Most impacts would be behavioral responses due to sonar used in testing activities, and the risk of injurious impacts is low. The predicted auditory injuries due to sonar would likely be from to hull-mounted sonar used in Anti-Submarine Warfare training activities. Predicted AINJ and non-auditory injury due to explosives is unlikely to occur, and activity-based mitigation may further reduce the likelihood of these impacts. The risk of repeated impacts on individuals is moderate. On average, individuals would be impacted three times per year.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Guadalupe fur seals have a fast pace of life. However, pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The Mexico stock of Guadalupe fur seals is migratory, so the risk of repeated impacts is likely lower for individuals in this population as they travel seasonally through their range. Although this stock is threatened and depleted, their population may be increasing. In addition, Guadalupe fur seals have shorter generation times, so this population would require less time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the Mexico stock of Guadalupe fur seals are unlikely.

Based on the analysis presented above, vessel, aircraft, and weapons noise produced during training activities may affect, but are not likely to adversely affect, Guadalupe fur seals. The use of sonars and explosives during training activities may affect, and are likely to adversely affect Guadalupe fur seals. Activities that involve the use of pile driving are not applicable to Guadalupe fur seals because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, vessel, aircraft, and weapons noise produced during testing activities may affect, but are not likely to adversely affect, Guadalupe fur seals. The use of sonars, explosives, and air guns during testing activities may affect, and are likely to adversely affect Guadalupe fur seals. Pile diving activities are not conducted during testing.

Table 2.4-79: Estimated Effects to the Mexico Stock of Guadalupe Fur Seals over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	(1)	-	-	-	-
Explosive	Navy Training	24	29	2	1	0
Explosive	Navy Testing	35	43	6	1	0
Explosive	USCG Training	(1)	-	-	-	-
Sonar	Navy Training	105,220	37,448	15	-	-
Sonar	Navy Testing	21,472	1,846	2	-	-
Sonar	USCG Training	1,863	2	-	-	-
Maximum Annual Total		**128,616**	**39,368**	**25**	**2**	**0**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
48,780	3.44	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	40%	7%	1%
Cold	42%	7%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	31%
Medium Coordinated Anti-Submarine Warfare	Navy Training	13%
Small Joint Coordinated Anti-Submarine Warfare	Navy Training	8%
Submarine Sonar Maintenance and Systems Checks	Navy Training	7%
Composite Training Unit Exercise (Strike Group)	Navy Training	7%
Surface Ship Sonar Maintenance and Systems Checks	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.3.6 California Sea Lion (*Zalophus californianus*)

The only stock of California sea lions in the Study Area is the United States stock. Sea lions are in the OCW hearing group and the Pinniped behavioral group. Model-predicted impacts are presented in Table 2.4-80.

California sea lions are found in the southern portion of the California Study Area and not the Hawaii Study Area. They are found in coastal waters and forage primarily in the open ocean over the continental shelf and slope and pelagic waters. They range from southern Mexico to the Gulf of Alaska, with seasonal shifts in their distribution to the northwest in the fall and southeast during the winter and spring.

Most predicted auditory impacts on California sea lions are due to sonar and explosives used in Navy training activities. The individual risk of injurious impacts is low. Auditory injuries would be due to explosives, sonar, and pile driving, while non-auditory injuries would be due to explosives. For pile driving, the implementation of 'soft start' procedures that may warn California sea lions to avoid the area, or haul out, prior to receiving sound levels that could produce these effects. Furthermore, the risk of AINJ or TTS from pile driving may be reduced further through visual observation mitigation. It is more likely that California sea lions may experience short-term behavioral impacts from this activity. A small number of mortalities due to explosives used in training and testing over seven years is predicted. However, the average risk of injurious impacts on individuals is low. The largest proportion of impacts on this species would be behavioral responses to sonar used in Navy training and testing activities and Intelligence, Surveillance, Reconnaissance activities. The risk of repeated impacts on individuals is high. On average, individuals would be impacted seven times per year.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. California sea lions have a fast pace of life. However, pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The movement ecology of California sea lions is dependent on demographics, but all individuals typically have residential site fidelity during the breeding season (summer). At the end of the breeding season, a portion of the population (females and young) stay in the area while another portion (typically males) migrates northward. Additionally, certain subpopulations of California sea lions (e.g., San Clemente Island population) tend to remain in Southern California year-round. The risk of repeated impacts on individuals who migrate seasonally may be lower compared to individuals who have site fidelity in areas that overlap with proposed activities. However, the entire United States stock of California sea lions is stable, and since this species has shorter generation times, this population would require less time to recover if significantly impacted.

Several instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the California sea lion are unlikely.

Table 2.4-80: Estimated Effects to the United States Stock California Sea Lions over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	8	(1)	-	-	-
Explosive	Navy Training	3,254	4,576	313	43	4
Explosive	Navy Testing	842	1,046	161	14	1
Explosive	USCG Training	2	2	0	0	-
Pile Driving	Navy Training	16,992	1,891	61	-	-
Sonar	Navy Training	662,716	186,625	115	-	-
Sonar	Navy Testing	928,540	67,321	16	-	-
Sonar	USCG Training	14,931	2	-	-	-
Maximum Annual Total		**1,627,285**	**261,464**	**666**	**57**	**5**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
257,606	7.33	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	35%	10%	2%
Cold	39%	12%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	16%
Unmanned Underwater Vehicle Testing	Navy Testing	12%
Anti-Submarine Warfare Torpedo Exercise - Ship	Navy Training	12%
Medium Coordinated Anti-Submarine Warfare	Navy Training	10%
Undersea Warfare Testing	Navy Testing	9%
Anti-Submarine Warfare Tracking Exercise - Ship	Navy Training	8%
At-Sea Sonar Testing	Navy Testing	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.3.7 Steller Sea Lion (*Eumetopias jubatus*)

The only stock of Steller sea lions in the Study Area is the Eastern United States stock. Sea lions are in the OCW hearing group and the Pinniped behavioral group. Model-predicted impacts are presented in Table 2.4-81.

The Stellar sea lion primarily ranges along the North Pacific Rim with most of the population occurring in the Gulf of Alaska and Aleutian Islands. In the Study Area, they are found with greater abundance in northern California and fewer occur in the Channel Islands and in Southern California waters. Most predicted auditory impacts are due to sonar used in Navy training and testing activities. While a few instances of auditory injury are predicted, most impacts would be TTS or behavioral responses. The risk of repeated impacts on individuals is low, and the risk of repeated injurious impacts is negligible.

The risk of repeated impacts on individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. Steller sea lions have a fast pace of life. However, pinnipeds have a relatively lower energy requirement for their body size, which may moderate any impact due to foraging disruption. The Eastern United States stock of Steller sea lions is residential, so the risk of repeated impacts is likely higher for individuals in this population as they have site fecundity to important haul outs along the California coastline including Año Nuevo Island and the Farallon Islands in Central California, which is directly adjacent to the NOCAL Range Complex. However, this population may be increasing, and since Steller sea lions have shorter generation times, this population would require less time to recover if significantly impacted.

A few instances of disturbance over a year are unlikely to have any long-term consequences for individuals, although individuals who experience injury may incur energetic costs. Based on the above analysis, long-term consequences for the Steller sea lion are unlikely.

Table 2.4-81: Estimated Effects to the Eastern United States Stock of Steller Sea Lions over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	5	8	2	-	-
Explosive	Navy Testing	0	(1)	0	-	-
Sonar	Navy Training	389	122	(1)	-	-
Sonar	Navy Testing	439	31	-	-	-
Sonar	USCG Training	4	-	-	-	-
Maximum Annual Total		**837**	**162**	**3**	**-**	**-**

Population Abundance Estimate	Annual Effects per Individual	Annual Injurious Effects per Individual
36,308	0.03	0.00

Season	Percent of Total Effects		
	SOCAL	PMSR	NOCAL
Warm	20%	1%	23%
Cold	29%	2%	25%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Medium Coordinated Anti-Submarine Warfare	Navy Training	33%
Intelligence, Surveillance, Reconnaissance (NAVWAR)	Navy Testing	24%
Unmanned Underwater Vehicle Testing	Navy Testing	13%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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2.4.4 Impacts on Mustelids

The southern sea otter is the only species of mustelid present in the Study Area. Sea otters are in the OCW hearing group. The updated OCW criteria reflects substantially greater susceptibility to auditory effects across their hearing range compared to previous analyses (Figure 2.2-1).

Southern sea otters would not be exposed to nearshore pile driving near Port Hueneme because there is no geographic overlap of this stressor with species occurrence. Impacts due to non-modeled acoustic stressors are discussed above in Section 2.1.4 (Impacts from Vessel Noise), Section 2.1.5 (Impacts from Aircraft Noise), and Section 2.1.6 (Impacts from Weapons Noise).

2.4.4.1 Southern Sea Otter (*Enhydra lutris*)*

The only stock of southern sea otters in the Study Area is the California stock which is threatened.

There are two populations of southern sea otters in the Study Area. The mainland population of sea otters ranges from Pigeon Point, north of Monterrey Bay, to just south of Point Conception on the central coast of California. These areas are shoreward of the NOCAL Range Complex and PMSR. The second population of southern sea otters around San Nicolas Island in the PMSR were translocated there by the United States Fish and Wildlife Service before 1991.[8] Sea otters prefer nearshore areas with kelp canopy but may occasionally be present in deeper waters when moving between areas or attempting to establish new habitat. The two populations of southern sea otters are considered largely residential and are not known to make seasonal migrations.

Southern sea otters are unlikely to be affected by noise from military readiness activities conducted offshore in the range complexes. Southern sea otters congregate in shallow, coastal environments, including bays and estuaries, as well as exposed coastal areas that are mostly shoreward and outside of the range complexes. They would not be exposed to noise from offshore military readiness activities when in inshore areas. Sonar activities would not occur close to shore in the area where sea otter habitat may overlap the PMSR near Point Conception, nor would explosives be used in the nearshore environments they inhabit on the mainland and at San Nicolas Island. Some coastal areas have higher levels of ambient noise that would mask or kelp forests that would attenuate underwater noise from military readiness activities. In addition, Ghoul and Reichmuth (2014) have shown that sea otters are not especially well adapted for hearing underwater, which suggests that the function of this sense has been less important in their survival and evolution than in comparison to pinnipeds. Sea otters also spend most of their time floating at the surface with their ears above the water.

Vessel noise would potentially disturb sea otters where training in the amphibious approach lanes would overlap mainland southern sea otter habitat around the southern border of the NOCAL Range Complex, from Mill Creek Beach to San Carpoforo Beach, and the three amphibious approach lanes bordering the northern portion of PMSR (near Morro Bay, Pismo Beach, and Vandenberg Space Force Base). Vessels in these amphibious approach lanes will avoid large areas of kelp canopy where sea otters are most likely to congregate. Sea otters spend most of their time on the surface, often together in large groups or rafts, and may be more visible to lookouts conducting visual observation mitigation.

The risk of repeated exposures to individuals and consequences to populations from disturbances of individuals can be mediated by certain life history traits of a species. This species is an extreme income breeder; their metabolism demands high caloric intake with minimal energy in reserve. Therefore, females are required to forage throughout lactation to meet both the caloric needs of themselves and their pups. As such small income breeders with a fast pace of life, southern sea otters are less resilient to missed foraging opportunities than larger marine mammals. While other marine mammals might avoid the same stressor, sea otters' dependence on constant and successful foraging opportunities likely drives this species to remain in productive foraging habitats even if foraging sites are near anthropogenic activities. Because the California stock of southern sea otters is residential, the risk of repeated exposure is higher for populations that have high site fidelity in locations that overlap frequently used training and testing sites. Although this stock of southern sea otters is threatened and depleted, the population in the HCTT Study Area may be somewhat stable, while the population at San Nicolas Island has been higher than the mainland population.

[8] Per the National Defense Authorization Act (NDAA) for Fiscal Year 2016, the provisions in the MMPA sections 101 and 102 and in the ESA sections 4 and 9 and do not apply to the incidental taking of southern sea otters in the designated Southern Sea Otter Military Readiness Areas at San Nicolas Island and San Clemente Island..

Based on the above analysis, significant impacts on individual sea otters are unlikely, and therefore it is unlikely that military readiness activities will produce long-term consequences for the California stock of southern sea otters.

Based on the analysis presented above, the use of sonar and explosives, and activities that produce aircraft and weapons noise during training activities <u>*would not affect*</u> *the mainland population of southern sea otters. Activities that produce vessel noise during training activities* <u>*may affect, but are not likely to adversely affect,*</u> *the mainland population of southern sea otters. Activities that involve the use of pile driving are* <u>*not applicable*</u> *to the mainland population of southern sea otters because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.*

Based on the analysis presented above, the use of sonar, explosives, and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities <u>*would not affect*</u> *the mainland population of southern sea otters. Pile diving activities are not conducted during testing.*

2.4.5 Impact Summary Tables

The tables in in this section show impacts on all stocks under the preferred alternative for the following:

- Maximum annual and seven-year total impacts due to sonar use during Navy training activities, during Navy testing activities, and during U.S. Coast Guard training activities. The maximum annual impacts per stock are the same values presented in each species impact assessment above. See Table 2.4-82 through Table 2.4-87.
- Maximum annual and seven-year total impacts due to air gun use during testing activities. See Table 2.4-88 and Table 2.4-89.
- Maximum annual and seven-year total impacts due to pile driving during training activities. See Table 2.4-90 and Table 2.4-91.
- Maximum annual and seven-year total impacts due to explosives during Navy training activities, during Navy testing activities (with Ship Shock Trials included in the total and broken out), during Coast Guard training activities, and during Army activities. See Table 2.4-92 through Table 2.4-100.
- A description of the methods used to calculate the estimated effects to marine mammal stocks from acoustic and explosive stressors over seven years of Navy training and testing is available in Section 2.4 (Species Impact Assessments).

2.4.5.1 Sonar Impact Summary Tables

2.4.5.1.1 Navy Training Sonar Impact Summary Tables

Table 2.4-82: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers over One Year of Maximum Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	1,447	3,124	27	-	-
	Central North Pacific	17	75	1	-	-
Fin whale	Hawai'i	21	65	1	-	-
	California/Oregon/Washington	3,704	9,797	54	1	-
Gray whale	Western North Pacific	72	97	2	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	1,274	3,175	43	1	-
	Central America/Southern Mexico - California/Oregon/Washington	547	1,341	19	-	-
Sei whale	Hawai'i	38	215	2	-	-
	Eastern North Pacific	83	219	3	-	-
False killer whale	Main Hawaiian Islands Insular	105	64	-	-	-
Killer whale	Southern Resident	0	-	-	-	-
Sperm whale	Hawai'i	1,237	412	1	-	-
	California/Oregon/Washington	2,999	892	3	-	-
Guadalupe fur seal	Mexico	128,616	39,368	25	2	0
Hawaiian monk seal	Hawai'i	536	153	4	1	0
Non ESA-Listed						
Bryde's whale	Hawai'i	68	341	3	-	-
	Eastern Tropical Pacific	111	211	5	-	-
Gray whale	Eastern North Pacific	7,151	9,560	167	0	-
Humpback whale	Hawai'i	1,227	1,807	24	-	-
Minke whale	Hawai'i	44	252	3	-	-
	California/Oregon/Washington	942	2,051	32	-	0
Bottlenose dolphin	O'ahu	7,108	124	5	1	1
	Maui Nui (formerly 4-Islands)	309	17	0	-	-
	Kaua'i/Ni'ihau	1,221	239	0	0	-
	Hawai'i Pelagic	37,284	6,029	23	2	1
	Hawai'i Island	5	4	-	-	-
	California/Oregon/Washington Offshore	21,232	6,826	14	1	0
	California Coastal	1,306	44	6	1	-
Dall's porpoise	California/Oregon/Washington	13,394	46,225	1,235	2	0
Dwarf sperm whale	Hawai'i	10,880	34,344	914	1	0
	California/Oregon/Washington	1,505	4,159	94	-	0
False killer whale	Northwest Hawaiian Islands	128	63	-	-	-
	Hawai'i Pelagic	936	734	1	-	-
	Eastern Tropical Pacific [Nsd]	1,710	827	2	0	-
Fraser's dolphin	Hawai'i	19,854	15,626	6	2	-
Killer whale	West Coast Transient	27	28	-	-	-
	Hawai'i	57	70	0	-	-
	Eastern North Pacific Offshore	830	193	4	0	-
Long-beaked common dolphin	California	253,952	42,926	128	24	4
Melon-headed whale	Kohala Resident	41	15	-	-	-
	Hawaiian Islands	16,187	15,269	13	0	0
Northern right whale dolphin	California/Oregon/Washington	23,867	21,647	19	2	1
Pacific white-sided dolphin	California/Oregon/Washington	45,571	23,639	38	4	2
Pantropical spotted dolphin	O'ahu	6,255	171	5	1	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
	Northeastern Offshore [Nsd]	60,809	36,817	45	2	2
	Maui Nui (formerly 4-Islands)	2,191	182	4	0	-
	Hawai'i Pelagic	24,231	20,159	16	3	0
	Hawai'i Island	2,902	3,122	6	1	-
Pygmy killer whale	Hawai'i	4,654	4,241	3	0	-
	California [Nsd]	622	173	0	0	-
Pygmy sperm whale	Hawai'i	10,954	34,833	935	1	0
	California/Oregon/Washington	1,549	4,066	107	0	-
Risso's dolphin	Hawai'i	3,564	2,994	4	0	-
	California/Oregon/Washington	33,191	10,642	17	4	0
Rough-toothed dolphin	Hawai'i	57,947	38,926	31	5	2
Short-beaked common dolphin	California/Oregon/Washington	1,499,861	669,693	806	71	18
Short-finned pilot whale	Hawai'i	11,626	5,678	6	1	0
	California/Oregon/Washington	3,353	926	9	2	1
Spinner dolphin	O'ahu/4 Islands	1,156	45	1	0	0
	Kaua'i Ni'ihau	3,561	885	2	0	0
	Hawai'i Pelagic	2,177	2,367	2	0	-
	Hawai'i Island	60	50	1	0	-
Striped dolphin	Hawai'i Pelagic	18,620	19,162	10	2	-
	California/Oregon/Washington	81,046	52,353	42	2	1
Baird's beaked whale	California/Oregon/Washington	10,112	62	0	-	-
Blainville's beaked whale	Hawai'i	7,508	34	-	-	-
Goose-beaked whale	Hawai'i	30,230	129	0	-	-
	California/Oregon/Washington	166,204	612	2	0	-
Harbor porpoise	San Francisco Russian River	9,898	62	26	-	-
	Northern California/Southern Oregon	481	0	-	-	-
	Morro Bay	4,152	221	87	1	0
	Monterey Bay	2,179	0	-	-	-
Longman's beaked whale	Hawai'i	18,219	97	1	-	-
Mesoplodont beaked whales	California/Oregon/Washington	92,419	420	2	0	0
California sea lion	United States	1,627,285	261,464	666	57	5
Harbor seal	California	51,674	19,309	254	7	1
Northern elephant seal	California Breeding	65,055	53,419	109	2	0
Northern fur seal	Eastern Pacific	23,105	10,090	11	1	0
	California	15,853	6,245	9	1	0
Steller sea lion	Eastern	837	162	3	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 2.4-83: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers Over Seven Years of Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	8,513	16,295	150	-	-
	Central North Pacific	92	432	2	-	-
Fin whale	Hawai'i	113	374	1	-	-
	California/Oregon/Washington	21,366	47,192	299	1	-
Gray whale	Western North Pacific	434	418	5	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	7,701	15,669	219	1	-
	Central America/Southern Mexico - California/Oregon/Washington	3,305	6,593	96	-	-
Sei whale	Hawai'i	227	1,210	5	-	-
	Eastern North Pacific	487	1,124	9	-	-
False killer whale	Main Hawaiian Islands Insular	637	372	-	-	-
Killer whale	Southern Resident	0	-	-	-	-
Sperm whale	Hawai'i	7,313	2,306	1	-	-
	California/Oregon/Washington	16,304	4,302	5	-	-
Guadalupe fur seal	Mexico	720,550	198,223	137	7	0
Hawaiian monk seal	Hawai'i	3,595	953	19	1	0
Non ESA-Listed						
Bryde's whale	Hawai'i	392	1,964	11	-	-
	Eastern Tropical Pacific	664	1,210	14	-	-
Gray whale	Eastern North Pacific	43,599	43,693	1,010	0	-
Humpback whale	Hawai'i	7,828	11,117	151	-	-
Minke whale	Hawai'i	259	1,439	13	-	-
	California/Oregon/Washington	5,735	10,381	193	-	0
Bottlenose dolphin	O'ahu	49,565	810	27	3	1
	Maui Nui (formerly 4-Islands)	2,049	102	0	-	-
	Kaua'i/Ni'ihau	7,657	1,657	0	0	-
	Hawai'i Pelagic	251,065	36,054	151	12	2
	Hawai'i Island	27	17	-	-	-
	California/Oregon/Washington Offshore	122,030	35,598	80	3	0
	California Coastal	8,502	259	41	1	-
Dall's porpoise	California/Oregon/Washington	76,921	228,511	6,781	5	0
Dwarf sperm whale	Hawai'i	67,933	194,468	5,102	1	0
	California/Oregon/Washington	8,583	21,510	517	-	0
False killer whale	Northwest Hawaiian Islands	775	390	-	-	-
	Hawai'i Pelagic	5,719	4,146	1	-	-
	Eastern Tropical Pacific [Nsd]	9,540	4,348	2	0	-
Fraser's dolphin	Hawai'i	122,248	88,278	32	2	-
Killer whale	West Coast Transient	137	124	-	-	-
	Hawai'i	337	396	0	-	-
	Eastern North Pacific Offshore	5,053	1,036	23	0	-
Long-beaked common dolphin	California	1,588,795	215,998	804	148	17
Melon-headed whale	Kohala Resident	250	82	-	-	-
	Hawaiian Islands	98,220	85,553	68	0	0
Northern right whale dolphin	California/Oregon/Washington	125,984	98,055	90	6	1
Pacific white-sided dolphin	California/Oregon/Washington	254,280	106,769	218	24	2
Pantropical spotted dolphin	O'ahu	43,081	1,119	22	1	-
	Northeastern Offshore [Nsd]	341,397	194,284	232	7	2
	Maui Nui (formerly 4-Islands)	14,107	1,085	18	0	-
	Hawai'i Pelagic	148,329	113,826	77	4	0
	Hawai'i Island	17,820	17,764	23	2	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Pygmy killer whale	Hawai'i	28,302	23,757	8	0	-
	California [Nsd]	3,499	859	0	0	-
Pygmy sperm whale	Hawai'i	68,237	197,085	5,220	1	0
	California/Oregon/Washington	8,830	21,038	609	0	-
Risso's dolphin	Hawai'i	21,364	16,676	5	0	-
	California/Oregon/Washington	188,061	52,786	107	18	0
Rough-toothed dolphin	Hawai'i	367,021	220,798	175	21	2
Short-beaked common dolphin	California/Oregon/Washington	8,473,412	3,331,011	4,634	441	107
Short-finned pilot whale	Hawai'i	72,315	32,457	25	1	0
	California/Oregon/Washington	19,691	4,841	44	12	4
Spinner dolphin	O'ahu/4 Islands	7,942	263	2	0	0
	Kaua'i Ni'ihau	22,186	6,148	6	0	0
	Hawai'i Pelagic	13,145	13,394	4	0	-
	Hawai'i Island	362	282	1	0	-
Striped dolphin	Hawai'i Pelagic	112,710	106,884	48	4	-
	California/Oregon/Washington	453,209	270,965	222	9	1
Baird's beaked whale	California/Oregon/Washington	55,858	291	0	-	-
Blainville's beaked whale	Hawai'i	45,810	194	-	-	-
Goose-beaked whale	Hawai'i	184,319	720	0	-	-
	California/Oregon/Washington	936,000	3,012	4	0	-
Harbor porpoise	San Francisco Russian River	48,554	346	169	-	-
	Northern California/Southern Oregon	2,339	0	-	-	-
	Morro Bay	24,909	1,407	588	2	0
	Monterey Bay	10,934	0	-	-	-
Longman's beaked whale	Hawai'i	111,612	540	4	-	-
Mesoplodont beaked whales	California/Oregon/Washington	518,892	2,046	6	0	0
California sea lion	United States	9,344,167	1,206,972	4,203	369	27
Harbor seal	California	282,977	104,852	1,598	44	7
Northern elephant seal	California Breeding	379,100	247,160	643	2	0
Northern fur seal	Eastern Pacific	114,217	44,579	53	2	0
	California	78,553	27,745	44	3	0
Steller sea lion	Eastern	4,601	745	13	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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2.4.5.1.2 Navy Testing Sonar Impact Summary Tables

Table 2.4-84: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers Over a Maximum Year of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	696	1,094	8
	Central North Pacific	5	19	(1)
Fin whale	Hawai'i	5	19	(1)
	California/Oregon/Washington	1,741	4,144	21
Gray whale	Western North Pacific	50	67	1
Humpback whale	Mainland Mexico - California/Oregon/Washington	818	1,155	8
	Central America/Southern Mexico - California/Oregon/Washington	343	472	4
Sei whale	Hawai'i	11	41	(1)
	Eastern North Pacific	37	65	(1)
False killer whale	Main Hawaiian Islands Insular	32	9	-
Killer whale	Southern Resident	0	-	-
Sperm whale	Hawai'i	288	56	0
	California/Oregon/Washington	834	129	-
Guadalupe fur seal	Mexico	21,472	1,846	2
Hawaiian monk seal	Hawai'i	58	33	(1)
Non ESA-Listed				
Bryde's whale	Hawai'i	22	75	(1)
	Eastern Tropical Pacific	47	89	2
Gray whale	Eastern North Pacific	4,876	6,722	64
Humpback whale	Hawai'i	348	358	4
Minke whale	Hawai'i	12	50	(1)
	California/Oregon/Washington	563	718	7
Bottlenose dolphin	O'ahu	407	35	(1)
	Maui Nui (formerly 4-Islands)	121	12	0
	Kaua'i/Ni'ihau	276	5	-
	Hawai'i Pelagic	4,805	842	1
	Hawai'i Island	3	-	-
	California/Oregon/Washington Offshore	9,699	1,286	(1)
	California Coastal	811	20	-
Dall's porpoise	California/Oregon/Washington	6,191	8,086	222
Dwarf sperm whale	Hawai'i	2,189	6,048	371
	California/Oregon/Washington	519	709	26
False killer whale	Northwest Hawaiian Islands	30	8	-
	Hawai'i Pelagic	192	95	(1)
	Eastern Tropical Pacific [Nsd]	332	60	0
Fraser's dolphin	Hawai'i	3,562	1,524	(1)
Killer whale	West Coast Transient	7	1	-
	Hawai'i	14	8	-
	Eastern North Pacific Offshore	399	75	0
Long-beaked common dolphin	California	181,795	11,646	6
Melon-headed whale	Kohala Resident	25	6	-
	Hawaiian Islands	3,396	1,711	2
Northern right whale dolphin	California/Oregon/Washington	7,934	1,997	2
Pacific white-sided dolphin	California/Oregon/Washington	23,127	3,851	2
Pantropical spotted dolphin	O'ahu	748	58	(1)
	Northeastern Offshore [Nsd]	12,181	2,468	2
	Maui Nui (formerly 4-Islands)	1,358	157	(1)
	Hawai'i Pelagic	5,521	2,324	2

Species	Stock or Population	BEH	TTS	AINJ
	Hawai'i Island	789	234	(1)
Pygmy killer whale	Hawai'i	928	481	(1)
	California Nsd	260	53	-
Pygmy sperm whale	Hawai'i	2,243	6,137	373
	California/Oregon/Washington	525	743	23
Risso's dolphin	Hawai'i	745	396	(1)
	California/Oregon/Washington	15,852	2,686	1
Rough-toothed dolphin	Hawai'i	11,455	4,768	3
Short-beaked common dolphin	California/Oregon/Washington	611,376	119,400	58
Short-finned pilot whale	Hawai'i	2,625	734	(1)
	California/Oregon/Washington	1,899	371	(1)
Spinner dolphin	O'ahu/4 Islands	180	28	0
	Kaua'i Ni'ihau	901	16	-
	Hawai'i Pelagic	473	265	(1)
	Hawai'i Island	13	0	-
Striped dolphin	Hawai'i Pelagic	3,793	2,473	1
	California/Oregon/Washington	16,581	5,362	2
Baird's beaked whale	California/Oregon/Washington	2,823	5	-
Blainville's beaked whale	Hawai'i	1,702	2	-
Goose-beaked whale	Hawai'i	6,945	8	-
	California/Oregon/Washington	55,207	92	-
Harbor porpoise	San Francisco Russian River	3,023	6	0
	Northern California/Southern Oregon	124	-	-
	Morro Bay	254	3	(1)
	Monterey Bay	865	-	-
Longman's beaked whale	Hawai'i	4,106	12	-
Mesoplodont beaked whales	California/Oregon/Washington	27,697	62	-
California sea lion	United States	928,540	67,321	16
Harbor seal	California	38,391	15,461	3
Northern elephant seal	California Breeding	34,434	13,065	5
Northern fur seal	Eastern Pacific	3,080	183	(1)
	California	1,769	87	0
Steller sea lion	Eastern	439	31	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 2.4-85: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers Over Seven Years of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	4,028	5,743	52
	Central North Pacific	27	107	2
Fin whale	Hawai'i	29	114	1
	California/Oregon/Washington	10,107	19,655	117
Gray whale	Western North Pacific	302	233	3
Humpback whale	Mainland Mexico - California/Oregon/Washington	4,947	5,553	43
	Central America/Southern Mexico - California/Oregon/Washington	2,076	2,269	23
Sei whale	Hawai'i	57	230	3
	Eastern North Pacific	215	345	1
False killer whale	Main Hawaiian Islands Insular	171	53	-
Killer whale	Southern Resident	0	-	-
Sperm whale	Hawai'i	1,452	291	0
	California/Oregon/Washington	4,350	594	-
Guadalupe fur seal	Mexico	120,817	11,643	10
Hawaiian monk seal	Hawai'i	314	199	1
Non ESA-Listed				
Bryde's whale	Hawai'i	112	412	1
	Eastern Tropical Pacific	275	517	8
Gray whale	Eastern North Pacific	28,937	24,742	335
Humpback whale	Hawai'i	2,045	2,082	27
Minke whale	Hawai'i	64	283	1
	California/Oregon/Washington	3,412	3,555	43
Bottlenose dolphin	O'ahu	2,727	237	1
	Maui Nui (formerly 4-Islands)	751	72	0
	Kaua'i/Ni'ihau	1,559	27	-
	Hawai'i Pelagic	28,873	4,998	7
	Hawai'i Island	19	-	-
	California/Oregon/Washington Offshore	55,144	6,926	3
	California Coastal	5,123	103	-
Dall's porpoise	California/Oregon/Washington	34,212	43,404	1,300
Dwarf sperm whale	Hawai'i	10,769	31,271	1,805
	California/Oregon/Washington	2,796	3,966	149
False killer whale	Northwest Hawaiian Islands	150	47	-
	Hawai'i Pelagic	987	502	1
	Eastern Tropical Pacific [Nsd]	1,831	392	0
Fraser's dolphin	Hawai'i	18,148	7,963	2
Killer whale	West Coast Transient	45	7	-
	Hawai'i	71	42	-
	Eastern North Pacific Offshore	2,318	440	0
Long-beaked common dolphin	California	1,156,935	57,311	31
Melon-headed whale	Kohala Resident	161	34	-
	Hawaiian Islands	17,285	9,306	13
Northern right whale dolphin	California/Oregon/Washington	43,020	8,762	9
Pacific white-sided dolphin	California/Oregon/Washington	132,034	17,006	13
Pantropical spotted dolphin	O'ahu	4,749	392	2
	Northeastern Offshore [Nsd]	67,222	16,411	10
	Maui Nui (formerly 4-Islands)	8,514	943	1
	Hawai'i Pelagic	28,528	12,527	9
	Hawai'i Island	4,524	1,389	1
Pygmy killer whale	Hawai'i	4,641	2,510	1

Species	Stock or Population	BEH	TTS	AINJ
	California [Nsd]	1,376	257	-
Pygmy sperm whale	Hawai'i	10,987	31,760	1,821
	California/Oregon/Washington	2,819	4,116	129
Risso's dolphin	Hawai'i	3,652	2,091	2
	California/Oregon/Washington	86,994	12,028	5
Rough-toothed dolphin	Hawai'i	62,028	25,394	15
Short-beaked common dolphin	California/Oregon/Washington	3,312,917	550,748	324
Short-finned pilot whale	Hawai'i	14,186	3,955	2
	California/Oregon/Washington	10,796	2,075	1
Spinner dolphin	O'ahu/4 Islands	1,120	155	0
	Kaua'i Ni'ihau	5,096	90	-
	Hawai'i Pelagic	2,345	1,445	1
	Hawai'i Island	82	0	-
Striped dolphin	Hawai'i Pelagic	18,660	12,807	6
	California/Oregon/Washington	88,084	29,998	12
Baird's beaked whale	California/Oregon/Washington	16,049	23	-
Blainville's beaked whale	Hawai'i	8,904	13	-
Goose-beaked whale	Hawai'i	36,195	44	-
	California/Oregon/Washington	295,610	393	-
Harbor porpoise	San Francisco Russian River	18,554	36	0
	Northern California/Southern Oregon	763	-	-
	Morro Bay	1,660	19	1
	Monterey Bay	5,307	-	-
Longman's beaked whale	Hawai'i	21,483	61	-
Mesoplodont beaked whales	California/Oregon/Washington	146,347	259	-
California sea lion	United States	5,191,344	245,578	71
Harbor seal	California	204,018	81,833	14
Northern elephant seal	California Breeding	203,952	54,851	27
Northern fur seal	Eastern Pacific	18,776	1,111	1
	California	10,740	521	0
Steller sea lion	Eastern	2,678	174	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.1.3 Coast Guard Training Sonar Impact Summary Tables

Table 2.4-86: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers Over a Maximum Year of Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	18	-	-
	Central North Pacific	(1)	-	-
Fin whale	Hawai'i	2	-	-
	California/Oregon/Washington	62	-	-
Gray whale	Western North Pacific	(1)	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	14	-	-
	Central America/Southern Mexico - California/Oregon/Washington	7	-	-
Sei whale	Hawai'i	1	-	-
	Eastern North Pacific	1	-	-
False killer whale	Main Hawaiian Islands Insular	4	-	-
Sperm whale	Hawai'i	7	-	-
	California/Oregon/Washington	28	-	-
Guadalupe fur seal	Mexico	1,863	2	-
Hawaiian monk seal	Hawai'i	1	-	-
Non ESA-Listed				
Bryde's whale	Hawai'i	2	-	-
	Eastern Tropical Pacific	1	-	-
Gray whale	Eastern North Pacific	15	-	-
Humpback whale	Hawai'i	7	-	-
Minke whale	Hawai'i	2	-	-
	California/Oregon/Washington	7	-	-
Bottlenose dolphin	Hawai'i Pelagic	33	-	-
	California/Oregon/Washington Offshore	119	-	-
	California Coastal	2	-	-
Dall's porpoise	California/Oregon/Washington	169	239	-
Dwarf sperm whale	Hawai'i	159	225	2
	California/Oregon/Washington	16	34	-
False killer whale	Northwest Hawaiian Islands	2	-	-
	Hawai'i Pelagic	12	-	-
	Eastern Tropical Pacific [Nsd]	16	-	-
Fraser's dolphin	Hawai'i	17	-	-
Killer whale	West Coast Transient	1	-	-
	Hawai'i	2	-	-
	Eastern North Pacific Offshore	1	-	-
Long-beaked common dolphin	California	924	1	-
Melon-headed whale	Hawaiian Islands	223	-	-
Northern right whale dolphin	California/Oregon/Washington	249	2	-
Pacific white-sided dolphin	California/Oregon/Washington	246	1	-
Pantropical spotted dolphin	O'ahu	1	-	-
	Northeastern Offshore [Nsd]	490	-	-
	Hawai'i Pelagic	226	-	-
	Hawai'i Island	24	-	-
Pygmy killer whale	Hawai'i	56	-	-
	California [Nsd]	3	-	-
Pygmy sperm whale	Hawai'i	160	192	-
	California/Oregon/Washington	17	31	-
Risso's dolphin	Hawai'i	35	-	-
	California/Oregon/Washington	187	-	-

Species	Stock or Population	BEH	TTS	AINJ
Rough-toothed dolphin	Hawai'i	406	-	-
Short-beaked common dolphin	California/Oregon/Washington	9,634	19	-
Short-finned pilot whale	Hawai'i	83	-	-
	California/Oregon/Washington	10	-	-
Spinner dolphin	Hawai'i Pelagic	24	-	-
Striped dolphin	Hawai'i Pelagic	247	2	-
	California/Oregon/Washington	775	-	-
Baird's beaked whale	California/Oregon/Washington	54	-	-
Blainville's beaked whale	Hawai'i	25	-	-
Goose-beaked whale	Hawai'i	143	-	-
	California/Oregon/Washington	653	-	-
Harbor porpoise	San Francisco Russian River	2	-	-
Longman's beaked whale	Hawai'i	145	-	-
Mesoplodont beaked whales	California/Oregon/Washington	415	-	-
California sea lion	United States	14,931	2	-
Harbor seal	California	140	-	-
Northern elephant seal	California Breeding	1,790	(1)	-
Northern fur seal	Eastern Pacific	633	-	-
	California	555	-	-
Steller sea lion	Eastern	4	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-87: Estimated Effects to Marine Mammal Stocks from Sonar and Other Active Transducers Over Seven Years of Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	124	-	-
	Central North Pacific	1	-	-
Fin whale	Hawai'i	8	-	-
	California/Oregon/Washington	432	-	-
Gray whale	Western North Pacific	2	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	96	-	-
	Central America/Southern Mexico - California/Oregon/Washington	45	-	-
Sei whale	Hawai'i	4	-	-
	Eastern North Pacific	4	-	-
False killer whale	Main Hawaiian Islands Insular	27	-	-
Sperm whale	Hawai'i	45	-	-
	California/Oregon/Washington	196	-	-
Guadalupe fur seal	Mexico	13,035	12	-
Hawaiian monk seal	Hawai'i	4	-	-
Non ESA-Listed				
Bryde's whale	Hawai'i	13	-	-
	Eastern Tropical Pacific	5	-	-
Gray whale	Eastern North Pacific	102	-	-
Humpback whale	Hawai'i	46	-	-
Minke whale	Hawai'i	14	-	-
	California/Oregon/Washington	48	-	-
Bottlenose dolphin	Hawai'i Pelagic	226	-	-
	California/Oregon/Washington Offshore	828	-	-
	California Coastal	12	-	-
Dall's porpoise	California/Oregon/Washington	1,178	1,669	-
Dwarf sperm whale	Hawai'i	1,109	1,575	12
	California/Oregon/Washington	108	235	-
False killer whale	Northwest Hawaiian Islands	9	-	-
	Hawai'i Pelagic	83	-	-
	Eastern Tropical Pacific [Nsd]	109	-	-
Fraser's dolphin	Hawai'i	113	-	-
Killer whale	West Coast Transient	5	-	-
	Hawai'i	10	-	-
	Eastern North Pacific Offshore	7	-	-
Long-beaked common dolphin	California	6,467	6	-
Melon-headed whale	Hawaiian Islands	1,558	-	-
Northern right whale dolphin	California/Oregon/Washington	1,742	12	-
Pacific white-sided dolphin	California/Oregon/Washington	1,722	7	-
Pantropical spotted dolphin	O'ahu	7	-	-
	Northeastern Offshore [Nsd]	3,428	-	-
	Hawai'i Pelagic	1,579	-	-
	Hawai'i Island	164	-	-
Pygmy killer whale	Hawai'i	390	-	-
	California [Nsd]	18	-	-
Pygmy sperm whale	Hawai'i	1,117	1,342	-
	California/Oregon/Washington	116	215	-
Risso's dolphin	Hawai'i	240	-	-
	California/Oregon/Washington	1,308	-	-
Rough-toothed dolphin	Hawai'i	2,838	-	-
Short-beaked common dolphin	California/Oregon/Washington	67,436	131	-

Species	Stock or Population	BEH	TTS	AINJ
Short-finned pilot whale	Hawai'i	578	-	-
	California/Oregon/Washington	69	-	-
Spinner dolphin	Hawai'i Pelagic	165	-	-
Striped dolphin	Hawai'i Pelagic	1,726	12	-
	California/Oregon/Washington	5,419	-	-
Baird's beaked whale	California/Oregon/Washington	378	-	-
Blainville's beaked whale	Hawai'i	170	-	-
Goose-beaked whale	Hawai'i	1,001	-	-
	California/Oregon/Washington	4,569	-	-
Harbor porpoise	San Francisco Russian River	11	-	-
Longman's beaked whale	Hawai'i	1,013	-	-
Mesoplodont beaked whales	California/Oregon/Washington	2,901	-	-
California sea lion	United States	104,514	13	-
Harbor seal	California	976	-	-
Northern elephant seal	California Breeding	12,529	1	-
Northern fur seal	Eastern Pacific	4,425	-	-
	California	3,885	-	-
Steller sea lion	Eastern	22	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.2 Air Gun Impact Summary Tables

Table 2.4-88: Estimated Effects to Marine Mammal Stocks from Air Guns Over a Maximum Year of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	0	-	-
Fin whale	California/Oregon/Washington	0	0	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	0	0	-
	Central America/Southern Mexico - California/Oregon/Washington	0	-	-
Sperm whale	Hawai'i	(1)	-	-
Guadalupe fur seal	Mexico	(1)	-	-
Non ESA-Listed				
Gray whale	Eastern North Pacific	0	-	-
Humpback whale	Hawai'i	(1)	-	-
Minke whale	California/Oregon/Washington	0	-	-
Bottlenose dolphin	Hawai'i Pelagic	(1)	-	-
	California/Oregon/Washington Offshore	(1)	-	-
Dall's porpoise	California/Oregon/Washington	9	8	1
Dwarf sperm whale	Hawai'i	8	5	(1)
	California/Oregon/Washington	1	1	-
Long-beaked common dolphin	California	3	-	-
Melon-headed whale	Hawaiian Islands	(1)	-	-
Northern right whale dolphin	California/Oregon/Washington	(1)	-	-
Pacific white-sided dolphin	California/Oregon/Washington	1	-	-
Pantropical spotted dolphin	Northeastern Offshore Nsd	2	-	-
	Hawai'i Pelagic	(1)	-	-
	Hawai'i Island	(1)	-	-
Pygmy killer whale	California Nsd	(1)	-	-
Pygmy sperm whale	Hawai'i	6	6	1
	California/Oregon/Washington	(1)	1	-
Risso's dolphin	California/Oregon/Washington	1	-	-
Rough-toothed dolphin	Hawai'i	(1)	-	-
Short-beaked common dolphin	California/Oregon/Washington	17	-	-
Short-finned pilot whale	Hawai'i	(1)	-	-
Striped dolphin	Hawai'i Pelagic	-	(1)	-
	California/Oregon/Washington	1	-	-
Goose-beaked whale	Hawai'i	(1)	-	-
Harbor porpoise	San Francisco Russian River	1	2	(1)
Mesoplodont beaked whales	California/Oregon/Washington	0	-	-
California sea lion	United States	8	(1)	-
Northern elephant seal	California Breeding	1	-	-
Northern fur seal	Eastern Pacific	(1)	-	-
	California	(1)	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-89: Estimated Effects to Marine Mammal Stocks from Air Guns over Seven Years of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Blue whale	Eastern North Pacific	0	-	-
Fin whale	California/Oregon/Washington	0	0	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	0	0	-
	Central America/Southern Mexico - California/Oregon/Washington	0	-	-
Sperm whale	Hawai'i	1	-	-
Guadalupe fur seal	Mexico	3	-	-
Non ESA-Listed				
Gray whale	Eastern North Pacific	0	-	-
Humpback whale	Hawai'i	1	-	-
Minke whale	California/Oregon/Washington	0	-	-
Bottlenose dolphin	Hawai'i Pelagic	3	-	-
	California/Oregon/Washington Offshore	2	-	-
Dall's porpoise	California/Oregon/Washington	58	48	4
Dwarf sperm whale	Hawai'i	50	34	1
	California/Oregon/Washington	4	3	-
Long-beaked common dolphin	California	13	-	-
Melon-headed whale	Hawaiian Islands	2	-	-
Northern right whale dolphin	California/Oregon/Washington	2	-	-
Pacific white-sided dolphin	California/Oregon/Washington	5	-	-
Pantropical spotted dolphin	Northeastern Offshore [Nsd]	9	-	-
	Hawai'i Pelagic	1	-	-
	Hawai'i Island	1	-	-
Pygmy killer whale	California [Nsd]	1	-	-
Pygmy sperm whale	Hawai'i	34	37	3
	California/Oregon/Washington	3	6	-
Risso's dolphin	California/Oregon/Washington	6	-	-
Rough-toothed dolphin	Hawai'i	1	-	-
Short-beaked common dolphin	California/Oregon/Washington	85	-	-
Short-finned pilot whale	Hawai'i	1	-	-
Striped dolphin	Hawai'i Pelagic	-	1	-
	California/Oregon/Washington	5	-	-
Goose-beaked whale	Hawai'i	1	-	-
Harbor porpoise	San Francisco Russian River	6	12	1
Mesoplodont beaked whales	California/Oregon/Washington	0	-	-
California sea lion	United States	33	1	-
Northern elephant seal	California Breeding	3	-	-
Northern fur seal	Eastern Pacific	2	-	-
	California	1	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.3 Pile Driving Impact Summary Tables

Table 2.4-90: Estimated Effects to Marine Mammal Stocks from Pile Driving over a Maximum Year of Navy Training

Species	Stock or Population	BEH	TTS	AINJ
Non ESA-Listed				
California sea lion	United States	16,992	1,891	61
Harbor seal	California	952	183	20

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-91: Estimated Effects to Marine Mammal Stocks from Pile Driving over Seven Years of Navy Training

Species	Stock or Population	BEH	TTS	AINJ
Non ESA-Listed				
California sea lion	United States	118,938	13,237	423
Harbor seal	California	6,664	1,281	138

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.4 Explosives Impact Summary Tables

2.4.5.4.1 Navy Training Explosives Impact Summary Tables

Table 2.4-92: Estimated Effects to Marine Mammal Stocks from Explosives over a Maximum Year of Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	65	81	1	-	-
	Central North Pacific	(1)	-	-	-	-
Fin whale	Hawai'i	(1)	0	0	-	-
	California/Oregon/Washington	98	114	5	1	-
Gray whale	Western North Pacific	(1)	(1)	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	35	85	3	-	-
	Central America/Southern Mexico - California/Oregon/Washington	18	27	(1)	-	-
Sei whale	Hawai'i	1	(1)	0	-	-
	Eastern North Pacific	5	1	0	-	-
False killer whale	Main Hawaiian Islands Insular	-	0	-	-	-
Sperm whale	Hawai'i	2	1	(1)	-	-
	California/Oregon/Washington	2	4	(1)	-	-
Guadalupe fur seal	Mexico	24	29	2	1	0
Hawaiian monk seal	Hawai'i	11	16	2	1	0
Non ESA-Listed						
Bryde's whale	Hawai'i	1	(1)	0	-	-
	Eastern Tropical Pacific	12	39	1	-	-
Gray whale	Eastern North Pacific	234	391	33	0	-
Humpback whale	Hawai'i	48	58	7	-	-
Minke whale	Hawai'i	1	(1)	-	-	-
	California/Oregon/Washington	29	81	9	-	-
Bottlenose dolphin	O'ahu	29	21	4	1	1
	Maui Nui (formerly 4-Islands)	0	1	-	-	-
	Kaua'i/Ni'ihau	-	(1)	0	0	-
	Hawai'i Pelagic	134	114	14	1	1
	Hawai'i Island	0	(1)	-	-	-
	California/Oregon/Washington Offshore	38	40	9	1	0
	California Coastal	9	15	6	1	-
Dall's porpoise	California/Oregon/Washington	155	433	185	1	-
Dwarf sperm whale	Hawai'i	272	407	171	1	0
	California/Oregon/Washington	12	35	13	-	-
False killer whale	Hawai'i Pelagic	(1)	(1)	-	-	-
	Eastern Tropical Pacific [Nsd]	0	1	-	-	-
Fraser's dolphin	Hawai'i	13	10	3	1	-
Killer whale	Hawai'i	-	0	0	-	-
	Eastern North Pacific Offshore	6	7	3	-	-
Long-beaked common dolphin	California	273	306	75	18	3
Melon-headed whale	Hawaiian Islands	4	3	1	0	0
Northern right whale dolphin	California/Oregon/Washington	2	4	(1)	1	0
Pacific white-sided dolphin	California/Oregon/Washington	77	73	16	3	1
Pantropical spotted dolphin	O'ahu	17	15	3	1	-
	Northeastern Offshore [Nsd]	15	11	5	1	1
	Maui Nui (formerly 4-Islands)	3	2	2	0	-
	Hawai'i Pelagic	11	13	3	1	0
	Hawai'i Island	1	8	2	1	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Pygmy killer whale	Hawai'i	2	2	(1)	0	-
	California [Nsd]	(1)	(1)	-	-	-
Pygmy sperm whale	Hawai'i	259	414	167	1	0
	California/Oregon/Washington	19	41	23	0	-
Risso's dolphin	Hawai'i	2	2	0	0	-
	California/Oregon/Washington	23	38	9	3	-
Rough-toothed dolphin	Hawai'i	72	63	6	3	1
Short-beaked common dolphin	California/Oregon/Washington	1,413	1,078	255	50	13
Short-finned pilot whale	Hawai'i	6	9	1	0	0
	California/Oregon/Washington	6	6	6	2	1
Spinner dolphin	O'ahu/4 Islands	4	3	(1)	0	0
	Kaua'i Ni'ihau	0	2	0	0	0
	Hawai'i Pelagic	(1)	(1)	0	0	-
	Hawai'i Island	1	(1)	(1)	0	-
Striped dolphin	Hawai'i Pelagic	11	5	1	1	-
	California/Oregon/Washington	12	23	4	1	1
Baird's beaked whale	California/Oregon/Washington	-	1	-	-	-
Blainville's beaked whale	Hawai'i	(1)	-	-	-	-
Goose-beaked whale	Hawai'i	2	1	0	-	-
	California/Oregon/Washington	6	13	(1)	-	-
Harbor porpoise	San Francisco Russian River	-	22	24	-	-
	Morro Bay	-	13	11	0	-
Longman's beaked whale	Hawai'i	(1)	(1)	1	-	-
Mesoplodont beaked whales	California/Oregon/Washington	2	5	(1)	-	-
California sea lion	United States	3,254	4,576	313	43	4
Harbor seal	California	1,510	2,050	214	6	1
Northern elephant seal	California Breeding	147	229	31	1	-
Northern fur seal	Eastern Pacific	(1)	2	(1)	0	-
	California	(1)	2	(1)	0	-
Steller sea lion	Eastern	5	8	2	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-93: Estimated Effects to Marine Mammal Stocks from Explosives over Seven Years of Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	415	535	4	-	-
	Central North Pacific	1	-	-	-	-
Fin whale	Hawai'i	1	0	0	-	-
	California/Oregon/Washington	633	747	35	1	-
Gray whale	Western North Pacific	2	2	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	225	574	18	-	-
	Central America/Southern Mexico - California/Oregon/Washington	115	181	3	-	-
Sei whale	Hawai'i	4	2	0	-	-
	Eastern North Pacific	34	6	0	-	-
False killer whale	Main Hawaiian Islands Insular	-	0	-	-	-
Sperm whale	Hawai'i	9	6	1	-	-
	California/Oregon/Washington	8	24	3	-	-
Guadalupe fur seal	Mexico	151	174	12	3	0
Hawaiian monk seal	Hawai'i	69	105	13	1	0
Non ESA-Listed						
Bryde's whale	Hawai'i	5	2	0	-	-
	Eastern Tropical Pacific	73	259	4	-	-
Gray whale	Eastern North Pacific	1,491	2,578	217	0	-
Humpback whale	Hawai'i	312	390	43	-	-
Minke whale	Hawai'i	4	1	-	-	-
	California/Oregon/Washington	182	529	63	-	-
Bottlenose dolphin	O'ahu	200	142	26	3	1
	Maui Nui (formerly 4-Islands)	0	4	-	-	-
	Kaua'i/Ni'ihau	-	1	0	0	-
	Hawai'i Pelagic	920	783	96	7	2
	Hawai'i Island	0	1	-	-	-
	California/Oregon/Washington Offshore	240	260	57	3	0
	California Coastal	59	103	41	1	-
Dall's porpoise	California/Oregon/Washington	975	2,787	1,214	1	-
Dwarf sperm whale	Hawai'i	1,692	2,630	1,109	1	0
	California/Oregon/Washington	75	219	83	-	-
False killer whale	Hawai'i Pelagic	2	3	-	-	-
	Eastern Tropical Pacific [Nsd]	0	4	-	-	-
Fraser's dolphin	Hawai'i	74	64	18	1	-
Killer whale	Hawai'i	-	0	0	-	-
	Eastern North Pacific Offshore	38	47	21	-	-
Long-beaked common dolphin	California	1,641	1,976	498	117	15
Melon-headed whale	Hawaiian Islands	24	20	5	0	0
Northern right whale dolphin	California/Oregon/Washington	13	24	1	3	0
Pacific white-sided dolphin	California/Oregon/Washington	463	470	101	19	1
Pantropical spotted dolphin	O'ahu	118	100	18	1	-
	Northeastern Offshore [Nsd]	93	75	29	6	1
	Maui Nui (formerly 4-Islands)	18	12	10	0	-
	Hawai'i Pelagic	69	87	15	2	0
	Hawai'i Island	7	55	13	2	-
Pygmy killer whale	Hawai'i	11	13	3	0	-
	California [Nsd]	1	1	-	-	-
Pygmy sperm whale	Hawai'i	1,617	2,711	1,084	1	0
	California/Oregon/Washington	117	272	153	0	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Risso's dolphin	Hawai'i	9	9	0	0	-
	California/Oregon/Washington	146	252	62	17	-
Rough-toothed dolphin	Hawai'i	481	426	38	17	1
Short-beaked common dolphin	California/Oregon/Washington	8,979	6,965	1,684	329	91
Short-finned pilot whale	Hawai'i	40	57	7	0	0
	California/Oregon/Washington	35	39	41	12	4
Spinner dolphin	O'ahu/4 Islands	27	19	2	0	0
	Kaua'i Ni'ihau	0	11	0	0	0
	Hawai'i Pelagic	2	2	0	0	-
	Hawai'i Island	7	2	1	0	-
Striped dolphin	Hawai'i Pelagic	59	31	4	3	-
	California/Oregon/Washington	73	148	27	6	1
Baird's beaked whale	California/Oregon/Washington	-	4	-	-	-
Blainville's beaked whale	Hawai'i	2	-	-	-	-
Goose-beaked whale	Hawai'i	11	4	0	-	-
	California/Oregon/Washington	36	89	2	-	-
Harbor porpoise	San Francisco Russian River	-	153	164	-	-
	Morro Bay	-	76	71	0	-
Longman's beaked whale	Hawai'i	2	3	4	-	-
Mesoplodont beaked whales	California/Oregon/Washington	11	34	2	-	-
California sea lion	United States	20,202	29,753	2,048	282	22
Harbor seal	California	9,224	12,668	1,343	42	7
Northern elephant seal	California Breeding	936	1,505	201	1	-
Northern fur seal	Eastern Pacific	1	14	1	0	-
	California	1	11	1	0	-
Steller sea lion	Eastern	31	50	12	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.4.2 Navy Testing Explosives Impact Summary Tables

Table 2.4-94: Estimated Effects to Marine Mammal Stocks from Explosives over a Maximum Year of Navy Testing (includes Small Ship Shock Trials)

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	21	25	2	-	-
Fin whale	Hawai'i	(1)	0	-	-	-
	California/Oregon/Washington	76	69	6	0	-
Gray whale	Western North Pacific	2	(1)	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	31	29	1	1	-
	Central America/Southern Mexico - California/Oregon/Washington	13	11	1	-	-
Sei whale	Hawai'i	0	0	-	-	-
	Eastern North Pacific	2	2	(1)	-	-
False killer whale	Main Hawaiian Islands Insular	(1)	(1)	-	-	-
Sperm whale	Hawai'i	0	(1)	-	-	-
	California/Oregon/Washington	2	1	(1)	-	-
Guadalupe fur seal	Mexico	35	43	6	1	0
Hawaiian monk seal	Hawai'i	8	9	1	-	-
Non ESA-Listed						
Bryde's whale	Hawai'i	(1)	1	0	-	-
	Eastern Tropical Pacific	3	3	(1)	-	-
Gray whale	Eastern North Pacific	123	56	5	0	-
Humpback whale	Hawai'i	40	32	2	-	-
Minke whale	Hawai'i	1	(1)	0	-	-
	California/Oregon/Washington	9	10	1	-	0
Bottlenose dolphin	O'ahu	-	(1)	0	0	-
	Maui Nui (formerly 4-Islands)	2	2	-	-	-
	Kaua'i/Ni'ihau	0	0	0	-	-
	Hawai'i Pelagic	51	32	4	1	-
	California/Oregon/Washington Offshore	6	7	1	0	-
	California Coastal	-	(1)	0	0	-
Dall's porpoise	California/Oregon/Washington	438	631	304	1	0
Dwarf sperm whale	Hawai'i	86	107	27	0	0
	California/Oregon/Washington	20	33	17	-	0
False killer whale	Hawai'i Pelagic	0	0	0	-	-
	Eastern Tropical Pacific [Nsd]	0	(1)	0	0	-
Fraser's dolphin	Hawai'i	0	0	0	-	-
Killer whale	Eastern North Pacific Offshore	2	1	(1)	0	-
Long-beaked common dolphin	California	72	83	27	6	1
Melon-headed whale	Hawaiian Islands	1	(1)	(1)	0	-
Northern right whale dolphin	California/Oregon/Washington	9	9	3	1	1
Pacific white-sided dolphin	California/Oregon/Washington	25	31	6	1	1
Pantropical spotted dolphin	O'ahu	-	(1)	0	-	-
	Northeastern Offshore [Nsd]	25	19	1	1	1
	Maui Nui (formerly 4-Islands)	19	8	1	0	-
	Hawai'i Pelagic	12	4	(1)	1	0
	Hawai'i Island	(1)	(1)	(1)	-	-
Pygmy killer whale	Hawai'i	(1)	0	0	0	-
	California [Nsd]	-	(1)	0	0	-
Pygmy sperm whale	Hawai'i	97	114	28	0	-
	California/Oregon/Washington	22	33	18	-	-
Risso's dolphin	Hawai'i	(1)	(1)	(1)	-	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
	California/Oregon/Washington	11	10	4	1	0
Rough-toothed dolphin	Hawai'i	42	23	3	1	1
Short-beaked common dolphin	California/Oregon/Washington	428	492	103	21	5
Short-finned pilot whale	Hawai'i	4	3	1	-	-
	California/Oregon/Washington	2	2	(1)	-	-
Spinner dolphin	O'ahu/4 Islands	1	(1)	-	-	-
	Kaua'i Ni'ihau	0	(1)	(1)	-	-
	Hawai'i Pelagic	0	(1)	0	0	-
	Hawai'i Island	0	-	-	-	-
Striped dolphin	Hawai'i Pelagic	2	1	(1)	0	-
	California/Oregon/Washington	16	22	4	1	0
Baird’s beaked whale	California/Oregon/Washington	1	(1)	0	-	-
Blainville’s beaked whale	Hawai'i	0	-	-	-	-
Goose-beaked whale	Hawai'i	1	(1)	0	-	-
	California/Oregon/Washington	8	3	1	0	-
Harbor porpoise	San Francisco Russian River	3	3	1	-	-
	Morro Bay	74	159	75	1	0
	Monterey Bay	0	-	-	-	-
Longman’s beaked whale	Hawai'i	0	0	-	-	-
Mesoplodont beaked whales	California/Oregon/Washington	6	3	1	0	0
California sea lion	United States	842	1,046	161	14	1
Harbor seal	California	170	158	14	1	0
Northern elephant seal	California Breeding	220	332	55	1	0
Northern fur seal	Eastern Pacific	19	28	7	1	0
	California	15	22	6	1	0
Steller sea lion	Eastern	0	(1)	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-95: Estimated Effects to Marine Mammal Stocks from Explosives over Seven Years of Navy Testing (includes Small Ship Shock Trials)

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	135	96	14	-	-
Fin whale	Hawai'i	2	0	-	-	-
	California/Oregon/Washington	451	284	39	0	-
Gray whale	Western North Pacific	9	1	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	187	172	5	1	-
	Central America/Southern Mexico - California/Oregon/Washington	80	67	5	-	-
Sei whale	Hawai'i	0	0	-	-	-
	Eastern North Pacific	11	8	1	-	-
False killer whale	Main Hawaiian Islands Insular	3	3	-	-	-
Sperm whale	Hawai'i	0	1	-	-	-
	California/Oregon/Washington	12	7	1	-	-
Guadalupe fur seal	Mexico	234	289	37	4	0
Hawaiian monk seal	Hawai'i	50	57	5	-	-
Non ESA-Listed						
Bryde’s whale	Hawai'i	1	6	0	-	-
	Eastern Tropical Pacific	16	20	1	-	-
Gray whale	Eastern North Pacific	713	353	30	0	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Humpback whale	Hawai'i	275	224	11	-	-
Minke whale	Hawai'i	3	1	0	-	-
	California/Oregon/Washington	58	63	6	-	0
Bottlenose dolphin	O'ahu	-	1	0	0	-
	Maui Nui (formerly 4-Islands)	13	14	-	-	-
	Kaua'i/Ni'ihau	0	0	0	-	-
	Hawai'i Pelagic	354	222	27	5	-
	California/Oregon/Washington Offshore	40	48	6	0	-
	California Coastal	-	2	0	0	-
Dall's porpoise	California/Oregon/Washington	2,808	3,857	1,748	4	0
Dwarf sperm whale	Hawai'i	548	669	135	0	0
	California/Oregon/Washington	127	205	96	-	0
False killer whale	Hawai'i Pelagic	0	0	0	-	-
	Eastern Tropical Pacific [Nsd]	0	3	0	0	-
Fraser's dolphin	Hawai'i	0	0	0	-	-
Killer whale	Eastern North Pacific Offshore	8	6	2	0	-
Long-beaked common dolphin	California	472	525	168	31	2
Melon-headed whale	Hawaiian Islands	4	2	1	0	-
Northern right whale dolphin	California/Oregon/Washington	59	55	20	3	1
Pacific white-sided dolphin	California/Oregon/Washington	168	204	36	5	1
Pantropical spotted dolphin	O'ahu	-	1	0	-	-
	Northeastern Offshore [Nsd]	171	128	4	1	1
	Maui Nui (formerly 4-Islands)	131	54	7	0	-
	Hawai'i Pelagic	78	27	2	1	0
	Hawai'i Island	3	2	1	-	-
Pygmy killer whale	Hawai'i	1	0	0	0	-
	California [Nsd]	-	1	0	0	-
Pygmy sperm whale	Hawai'i	614	718	142	0	-
	California/Oregon/Washington	145	200	109	-	-
Risso's dolphin	Hawai'i	2	1	1	-	-
	California/Oregon/Washington	71	62	21	1	0
Rough-toothed dolphin	Hawai'i	289	160	19	3	1
Short-beaked common dolphin	California/Oregon/Washington	2,819	3,129	601	112	16
Short-finned pilot whale	Hawai'i	26	20	3	-	-
	California/Oregon/Washington	14	11	1	-	-
Spinner dolphin	O'ahu/4 Islands	5	3	-	-	-
	Kaua'i Ni'ihau	0	1	1	-	-
	Hawai'i Pelagic	0	1	0	0	-
	Hawai'i Island	0	-	-	-	-
Striped dolphin	Hawai'i Pelagic	9	5	1	0	-
	California/Oregon/Washington	108	147	23	3	0
Baird's beaked whale	California/Oregon/Washington	5	2	0	-	-
Blainville's beaked whale	Hawai'i	0	-	-	-	-
Goose-beaked whale	Hawai'i	4	1	0	-	-
	California/Oregon/Washington	50	16	2	0	-
Harbor porpoise	San Francisco Russian River	15	18	4	-	-
	Morro Bay	495	1,091	516	2	0
	Monterey Bay	0	-	-	-	-
Longman's beaked whale	Hawai'i	0	0	-	-	-
Mesoplodont beaked whales	California/Oregon/Washington	35	21	4	0	0
California sea lion	United States	5,409	6,705	1,008	87	5
Harbor seal	California	1,030	977	90	2	0
Northern elephant seal	California Breeding	1,427	2,096	332	1	0
Northern fur seal	Eastern Pacific	117	177	42	2	0
	California	93	140	35	3	0

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Steller sea lion	Eastern	0	2	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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At most, Small Ship Shock Trials could occur once in seven years. The below results show the highest estimated impacts on each stock across all seasons.

Table 2.4-96: Estimated Effects to Marine Mammal Stocks from Small Ship Shock Trials over a Maximum Year of Navy Testing (1 Event)

Species	Stock	TTS	AINJ	INJ	MORT
ESA-Listed					
Blue whale	Eastern North Pacific	12	-	-	-
Fin whale	California/Oregon/Washington	24	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	2	0	0	-
	Central America/Southern Mexico - California/Oregon/Washington	1	0	-	-
Sei whale	Eastern North Pacific	0	-	-	-
Sperm whale	California/Oregon/Washington	0	0	-	-
Guadalupe fur seal	Mexico	0	-	-	-
Non ESA-Listed					
Minke whale	California/Oregon/Washington	1	0	-	-
Bottlenose dolphin	California/Oregon/Washington Offshore	0	0	0	-
Dall's porpoise	California/Oregon/Washington	39	34	-	0
Dwarf sperm whale	California/Oregon/Washington	2	2	-	-
Long-beaked common dolphin	California	4	1	1	1
Northern right whale dolphin	California/Oregon/Washington	0	0	0	0
Pacific white-sided dolphin	California/Oregon/Washington	1	-	0	0
Pantropical spotted dolphin	Northeastern Offshore Nsd	1	0	0	0
Pygmy sperm whale	California/Oregon/Washington	2	2	-	-
Risso's dolphin	California/Oregon/Washington	1	0	0	0
Short-beaked common dolphin	California/Oregon/Washington	17	5	3	3
Short-finned pilot whale	California/Oregon/Washington	0	-	-	-
Striped dolphin	California/Oregon/Washington	0	0	0	-
Baird's beaked whale	California/Oregon/Washington	0	0	-	-
Goose-beaked whale	California/Oregon/Washington	1	0	0	-
Mesoplodont beaked whales	California/Oregon/Washington	0	0	0	0
California sea lion	United States	6	1	0	0
Northern elephant seal	California Breeding	6	4	0	0

TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.4.3 Coast Guard Training Explosives Impact Summary Tables

Table 2.4-97: Estimated Effects to Marine Mammal Stocks from Explosives over a Maximum Year of U.S. Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	(1)	-	-	-	-
Fin whale	California/Oregon/Washington	0	0	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	(1)	0	-	-	-
	Central America/Southern Mexico - California/Oregon/Washington	0	0	-	-	-
Sei whale	Hawai'i	-	0	-	-	-
Sperm whale	California/Oregon/Washington	0	-	-	-	-
Guadalupe fur seal	Mexico	(1)	-	-	-	-
Non ESA-Listed						
Gray whale	Eastern North Pacific	0	(1)	-	-	-
Minke whale	California/Oregon/Washington	0	0	-	-	-
Bottlenose dolphin	California/Oregon/Washington Offshore	(1)	(1)	-	-	-
Dall's porpoise	California/Oregon/Washington	2	2	(1)	-	-
Dwarf sperm whale	Hawai'i	1	1	(1)	-	-
	California/Oregon/Washington	(1)	(1)	(1)	-	-
False killer whale	Eastern Tropical Pacific Nsd	(1)	-	(1)	-	-
Fraser's dolphin	Hawai'i	(1)	0	-	-	-
Long-beaked common dolphin	California	(1)	(1)	0	-	-
Melon-headed whale	Hawaiian Islands	(1)	-	-	-	-
Northern right whale dolphin	California/Oregon/Washington	0	0	-	-	-
Pacific white-sided dolphin	California/Oregon/Washington	0	0	-	-	-
Pantropical spotted dolphin	Northeastern Offshore Nsd	-	(1)	-	-	-
	Hawai'i Pelagic	-	(1)	-	-	-
	Hawai'i Island	0	0	-	-	-
Pygmy sperm whale	Hawai'i	1	(1)	(1)	-	-
	California/Oregon/Washington	(1)	(1)	0	-	-
Risso's dolphin	California/Oregon/Washington	0	(1)	-	-	-
Rough-toothed dolphin	Hawai'i	0	-	-	-	-
Short-beaked common dolphin	California/Oregon/Washington	3	2	(1)	-	-
Striped dolphin	Hawai'i Pelagic	-	0	0	-	-
	California/Oregon/Washington	-	(1)	-	-	-
Goose-beaked whale	California/Oregon/Washington	0	-	-	-	-
Harbor porpoise	San Francisco Russian River	0	0	0	-	-
Mesoplodont beaked whales	California/Oregon/Washington	(1)	-	0	-	-
California sea lion	United States	2	2	0	0	-
Harbor seal	California	(1)	0	-	-	-
Northern elephant seal	California Breeding	2	2	(1)	-	-
Northern fur seal	Eastern Pacific	0	(1)	-	-	-
	California	0	0	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-98: Estimated Effects to Marine Mammal Stocks from Explosives over Seven Years of Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Blue whale	Eastern North Pacific	1	-	-	-	-
Fin whale	California/Oregon/Washington	0	0	0	-	-
Humpback whale	Mainland Mexico - California/Oregon/Washington	1	0	-	-	-
	Central America/Southern Mexico - California/Oregon/Washington	0	0	-	-	-
Sei whale	Hawai'i	-	0	-	-	-
Sperm whale	California/Oregon/Washington	0	-	-	-	-
Guadalupe fur seal	Mexico	1	-	-	-	-
Non ESA-Listed						
Gray whale	Eastern North Pacific	0	1	-	-	-
Minke whale	California/Oregon/Washington	0	0	-	-	-
Bottlenose dolphin	California/Oregon/Washington Offshore	1	1	-	-	-
Dall's porpoise	California/Oregon/Washington	11	9	3	-	-
Dwarf sperm whale	Hawai'i	6	5	1	-	-
	California/Oregon/Washington	1	1	1	-	-
False killer whale	Eastern Tropical Pacific [Nsd]	1	-	1	-	-
Fraser's dolphin	Hawai'i	1	0	-	-	-
Long-beaked common dolphin	California	1	1	0	-	-
Melon-headed whale	Hawaiian Islands	1	-	-	-	-
Northern right whale dolphin	California/Oregon/Washington	0	0	-	-	-
Pacific white-sided dolphin	California/Oregon/Washington	0	0	-	-	-
Pantropical spotted dolphin	Northeastern Offshore [Nsd]	-	1	-	-	-
	Hawai'i Pelagic	-	1	-	-	-
	Hawai'i Island	0	0	-	-	-
Pygmy sperm whale	Hawai'i	7	3	1	-	-
	California/Oregon/Washington	1	1	0	-	-
Risso's dolphin	California/Oregon/Washington	0	1	-	-	-
Rough-toothed dolphin	Hawai'i	0	-	-	-	-
Short-beaked common dolphin	California/Oregon/Washington	17	14	2	-	-
Striped dolphin	Hawai'i Pelagic	-	0	0	-	-
	California/Oregon/Washington	-	1	-	-	-
Goose-beaked whale	California/Oregon/Washington	0	-	-	-	-
Harbor porpoise	San Francisco Russian River	0	0	0	-	-
Mesoplodont beaked whales	California/Oregon/Washington	1	-	0	-	-
California sea lion	United States	10	8	0	0	-
Harbor seal	California	1	0	-	-	-
Northern elephant seal	California Breeding	8	11	1	-	-
Northern fur seal	Eastern Pacific	0	1	-	-	-
	California	0	0	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

2.4.5.4.4 Army Training Explosives Impact Summary Tables

Table 2.4-99: Estimated Effects to Marine Mammal Stocks from Explosives over a Maximum Year of Army Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Hawaiian monk seal	Hawai'i	(1)	-	-	-	-
Non ESA-Listed						
Bryde's whale	Hawai'i	(1)	(1)	-	-	-
Humpback whale	Hawai'i	3	1	-	-	-
Minke whale	Hawai'i	(1)	-	-	-	-
Bottlenose dolphin	Hawai'i Pelagic	2	1	(1)	0	-
Dwarf sperm whale	Hawai'i	51	46	12	-	-
Fraser's dolphin	Hawai'i	2	3	1	1	-
Melon-headed whale	Kohala Resident	1	(1)	-	-	-
	Hawaiian Islands	1	(1)	(1)	-	-
Pantropical spotted dolphin	Maui Nui (formerly 4-Islands)	-	(1)	-	-	-
	Hawai'i Pelagic	2	1	(1)	1	0
Pygmy killer whale	Hawai'i	(1)	-	-	-	-
Pygmy sperm whale	Hawai'i	57	51	15	-	-
Risso's dolphin	Hawai'i	-	-	(1)	0	-
Rough-toothed dolphin	Hawai'i	3	2	(1)	1	-
Short-finned pilot whale	Hawai'i	2	1	(1)	1	-
Striped dolphin	Hawai'i Pelagic	1	2	(1)	1	-
Blainville's beaked whale	Hawai'i	-	(1)	-	-	-
Goose-beaked whale	Hawai'i	(1)	(1)	0	-	-
Longman's beaked whale	Hawai'i	(1)	(1)	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 2.4-100: Estimated Effects to Marine Mammal Stocks from Explosives over Seven Years of Army Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Hawaiian monk seal	Hawai'i	3	-	-	-	-
Non ESA-Listed						
Bryde's whale	Hawai'i	2	1	-	-	-
Humpback whale	Hawai'i	15	7	-	-	-
Minke whale	Hawai'i	3	-	-	-	-
Bottlenose dolphin	Hawai'i Pelagic	10	4	1	0	-
Dwarf sperm whale	Hawai'i	355	322	84	-	-
Fraser's dolphin	Hawai'i	12	15	5	1	-
Melon-headed whale	Kohala Resident	4	3	-	-	-
	Hawaiian Islands	5	3	1	-	-
Pantropical spotted dolphin	Maui Nui (formerly 4-Islands)	-	1	-	-	-
	Hawai'i Pelagic	8	6	1	1	0
Pygmy killer whale	Hawai'i	3	-	-	-	-
Pygmy sperm whale	Hawai'i	399	356	101	-	-
Risso's dolphin	Hawai'i	-	-	1	0	-
Rough-toothed dolphin	Hawai'i	17	14	1	1	-
Short-finned pilot whale	Hawai'i	9	6	2	1	-
Striped dolphin	Hawai'i Pelagic	7	10	1	1	-
Blainville's beaked whale	Hawai'i	-	1	-	-	-
Goose-beaked whale	Hawai'i	3	3	0	-	-
Longman's beaked whale	Hawai'i	2	1	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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2.5 Ranges to Effects

The following section provides the range (distance) over which specific physiological or behavioral effects are expected to occur based on the acoustic and explosive criteria in the *Criteria and Thresholds TR*, and the acoustic and explosive propagation calculations from the Navy Acoustic Effects Model described in the *Quantitative Analysis TR*. The ranges to effects are shown for representative sonar systems, air guns, and explosive bins from E1 (0.1–0.25 lb. NEW) to E16 (>7,500–14,500 lb. NEW). Ranges are determined by modeling the distance that noise from a source will need to propagate to reach exposure level thresholds specific to a hearing group that will cause behavioral response, TTS, AINJ, non-auditory injury, and mortality. Ranges to effects are utilized to help predict impacts from acoustic and explosive sources and assess the benefit of mitigation zones.

Tables present median and standard deviation ranges to effects for each hearing group, source or bin, bathymetric depth intervals of ≤200 m and >200 m to represent areas on an off the continental shelf, exposure duration (sonar), and representative cluster size (air guns and explosives). Ranges to effects consider propagation effects of sources modeled at different locations (i.e., analysis points), seasons, source depths, and radials (i.e., each analysis point considers propagation effects in different x-y directions by modeling 18 radials in azimuthal increments of 20° to obtain 360° coverage around an analysis point). The exception to this is ranges to effects for pile driving, which were calculated outside of the Navy Acoustic Effects Model, do not have variance in ranges, and are not presented as a summary statistic (e.g., median and standard deviation).

Boxplots visually present the distribution, variance, and outlier ranges for a given combination of a source or bin, hearing group, and effect. On the boxplots, outliers are plotted as dots, the lowest and highest non-outlier ranges are the extent of the left and right horizontal lines respectively that extend from the sides of a colored box, and the 25th, 50th (i.e., median), and 75th percentiles are the left edge, center line, and right edge of a colored box respectively.

2.5.1 Ranges to Effects for Sonar and Other Transducers

Ranges to effects for sonar were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a hearing group that would cause behavioral response, TTS, and AINJ, as described in the *Criteria and Thresholds TR*. The ranges do not account for an animal avoiding a source nor for the movement of the platform, both of which would influence the actual range to onset of auditory effects during an actual exposure.

The tables below provide the ranges to TTS and AINJ for an exposure duration of 1, 30, 60, and 120 seconds for six representative sonar systems. Due to the lower acoustic thresholds for TTS versus AINJ, ranges to TTS are longer. Successive pings can be expected to add together, further increasing the range to the onset of TTS and AINJ.

The mean, 5th, and 95th percentile behavioral response curves below, provide the probability of behavioral response as a function of range for the sensitive species (beaked whales and harbor porpoises), mysticete (all baleen whales), odontocete (most toothed whales, dolphins, and porpoises), and pinniped (true seals, sea lions, walruses, sea otters, polar bears) behavioral response groups.

Table 2.5-1: VLF Cetacean Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	160 m (30 m)	12 m (4 m)
		30 s	314 m (75 m)	21 m (6 m)
		60 s	426 m (97 m)	25 m (4 m)
		120 s	631 m (135 m)	35 m (6 m)
	>200 m	1 s	140 m (21 m)	0 m (1 m)
		30 s	260 m (50 m)	0 m (8 m)
		60 s	340 m (72 m)	23 m (10 m)
		120 s	500 m (116 m)	35 m (15 m)
MF1 Ship Sonar	≤200 m	1 s	1,069 m (254 m)	90 m (17 m)
		30 s	1,069 m (254 m)	90 m (17 m)
		60 s	1,528 m (467 m)	140 m (24 m)
		120 s	1,792 m (639 m)	180 m (32 m)
	>200 m	1 s	1,000 m (87 m)	85 m (3 m)
		30 s	1,000 m (87 m)	85 m (3 m)
		60 s	1,500 m (243 m)	130 m (7 m)
		120 s	1,889 m (470 m)	170 m (9 m)
MF1C Ship Sonar	≤200 m	1 s	1,069 m (254 m)	90 m (17 m)
		30 s	1,792 m (639 m)	180 m (32 m)
		60 s	2,319 m (1,027 m)	263 m (56 m)
		120 s	2,806 m (1,488 m)	390 m (73 m)
	>200 m	1 s	1,000 m (87 m)	85 m (3 m)
		30 s	1,889 m (470 m)	170 m (9 m)
		60 s	2,750 m (1,053 m)	250 m (23 m)
		120 s	3,847 m (1,552 m)	370 m (33 m)
MF1K Ship Sonar	≤200 m	1 s	193 m (37 m)	12 m (4 m)
		30 s	355 m (73 m)	24 m (2 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	470 m (83 m)	30 m (3 m)
		120 s	668 m (126 m)	45 m (13 m)
	>200 m	1 s	190 m (16 m)	5 m (5 m)
		30 s	340 m (36 m)	21 m (11 m)
		60 s	440 m (56 m)	25 m (3 m)
		120 s	625 m (70 m)	40 m (2 m)
Mine-Hunting Sonar	≤200 m	1 s	3 m (1 m)	0 m (0 m)
		30 s	6 m (1 m)	0 m (0 m)
		60 s	9 m (1 m)	0 m (0 m)
		120 s	13 m (2 m)	1 m (0 m)
	>200 m	1 s	0 m (0 m)	0 m (0 m)
		30 s	5 m (2 m)	0 m (0 m)
		60 s	8 m (3 m)	0 m (0 m)
		120 s	12 m (0 m)	0 m (0 m)
Sonobuoy Sonar	≤200 m	1 s	13 m (6 m)	0 m (0 m)
		30 s	25 m (6 m)	0 m (0 m)
		60 s	35 m (7 m)	0 m (1 m)
		120 s	50 m (4 m)	0 m (1 m)
	>200 m	1 s	0 m (6 m)	0 m (0 m)
		30 s	23 m (10 m)	0 m (0 m)
		60 s	35 m (11 m)	0 m (0 m)
		120 s	50 m (3 m)	0 m (0 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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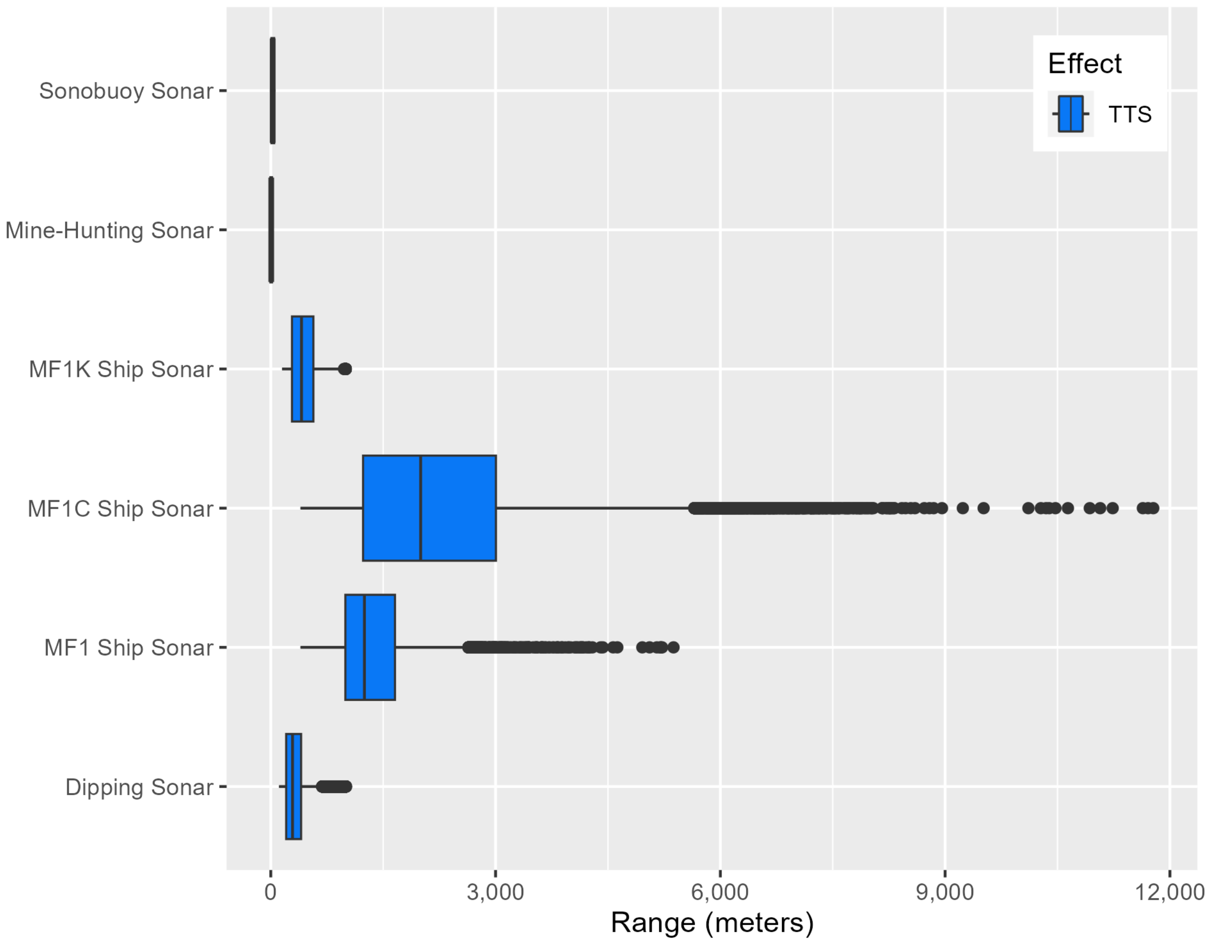

Figure 2.5-1: VLF Cetacean Ranges to Temporary Threshold Shift for Sonar

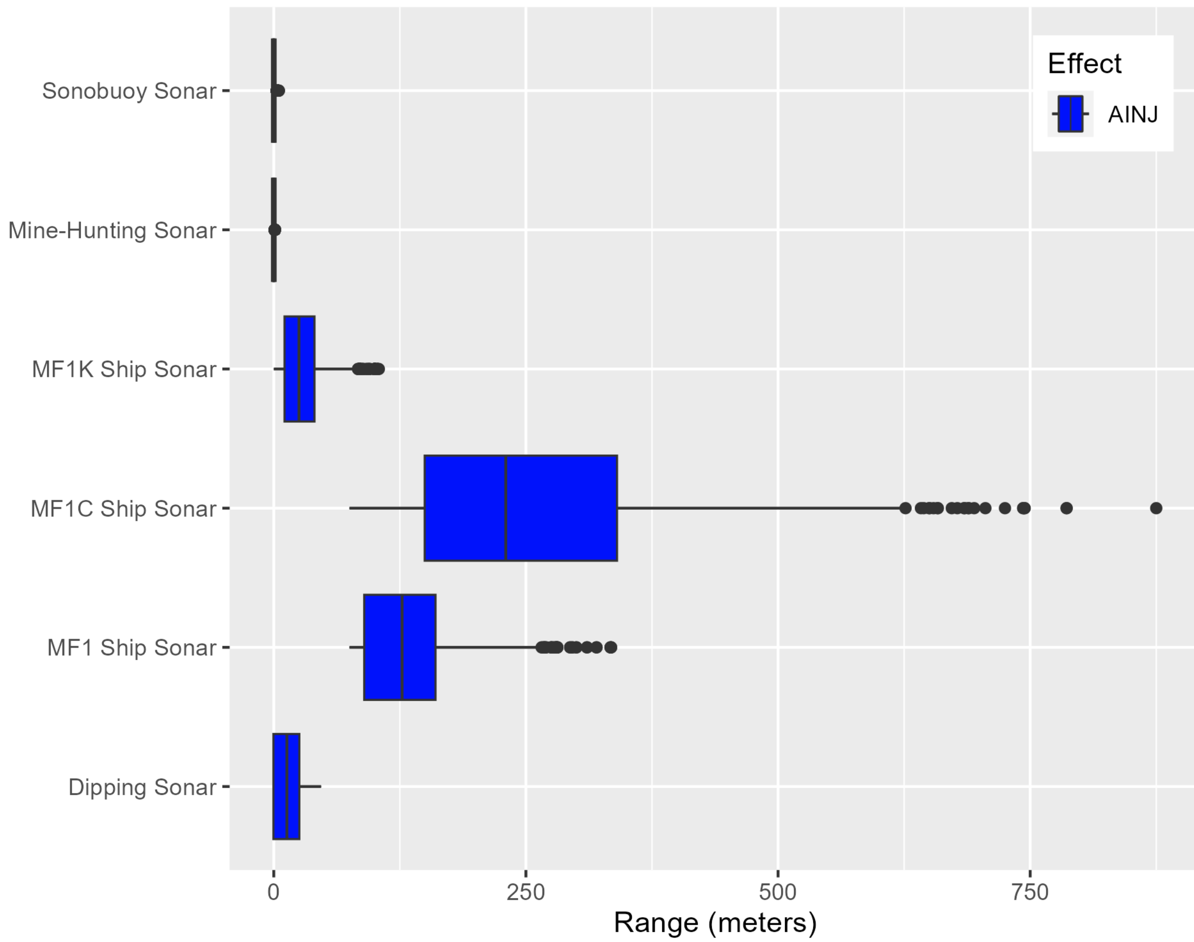

Figure 2.5-2: VLF Cetacean Ranges to Auditory Injury for Sonar

Table 2.5-2: LF Cetacean Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	160 m (55 m)	12 m (4 m)
		30 s	312 m (97 m)	21 m (6 m)
		60 s	412 m (116 m)	25 m (7 m)
		120 s	585 m (135 m)	35 m (10 m)
	>200 m	1 s	150 m (82 m)	0 m (6 m)
		30 s	240 m (125 m)	17 m (10 m)
		60 s	287 m (161 m)	25 m (13 m)
		120 s	410 m (131 m)	35 m (18 m)
MF1 Ship Sonar	≤200 m	1 s	1,069 m (281 m)	95 m (19 m)
		30 s	1,069 m (281 m)	95 m (19 m)
		60 s	1,500 m (502 m)	140 m (24 m)
		120 s	1,736 m (672 m)	180 m (30 m)
	>200 m	1 s	1,000 m (193 m)	90 m (6 m)
		30 s	1,000 m (193 m)	90 m (6 m)
		60 s	1,514 m (414 m)	140 m (13 m)
		120 s	2,056 m (714 m)	180 m (15 m)
MF1C Ship Sonar	≤200 m	1 s	1,069 m (281 m)	95 m (19 m)
		30 s	1,736 m (672 m)	180 m (30 m)
		60 s	2,181 m (1,069 m)	270 m (50 m)
		120 s	2,639 m (1,530 m)	400 m (69 m)
	>200 m	1 s	1,000 m (193 m)	90 m (6 m)
		30 s	2,056 m (714 m)	180 m (15 m)
		60 s	2,986 m (1,270 m)	260 m (22 m)
		120 s	4,153 m (1,788 m)	380 m (31 m)
MF1K Ship Sonar	≤200 m	1 s	200 m (34 m)	14 m (1 m)
		30 s	360 m (67 m)	25 m (1 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	480 m (84 m)	30 m (4 m)
		120 s	661 m (135 m)	45 m (14 m)
	>200 m	1 s	200 m (22 m)	12 m (1 m)
		30 s	350 m (34 m)	24 m (0 m)
		60 s	450 m (47 m)	30 m (0 m)
		120 s	650 m (94 m)	45 m (0 m)
Mine-Hunting Sonar	≤200 m	1 s	8 m (5 m)	0 m (0 m)
		30 s	15 m (8 m)	1 m (0 m)
		60 s	21 m (12 m)	2 m (1 m)
		120 s	30 m (12 m)	3 m (2 m)
	>200 m	1 s	8 m (5 m)	0 m (0 m)
		30 s	15 m (8 m)	0 m (0 m)
		60 s	21 m (12 m)	0 m (1 m)
		120 s	30 m (12 m)	0 m (1 m)
Sonobuoy Sonar	≤200 m	1 s	0 m (8 m)	0 m (0 m)
		30 s	25 m (12 m)	0 m (0 m)
		60 s	35 m (18 m)	0 m (0 m)
		120 s	55 m (25 m)	0 m (1 m)
	>200 m	1 s	0 m (7 m)	0 m (0 m)
		30 s	19 m (12 m)	0 m (0 m)
		60 s	35 m (19 m)	0 m (0 m)
		120 s	55 m (28 m)	0 m (1 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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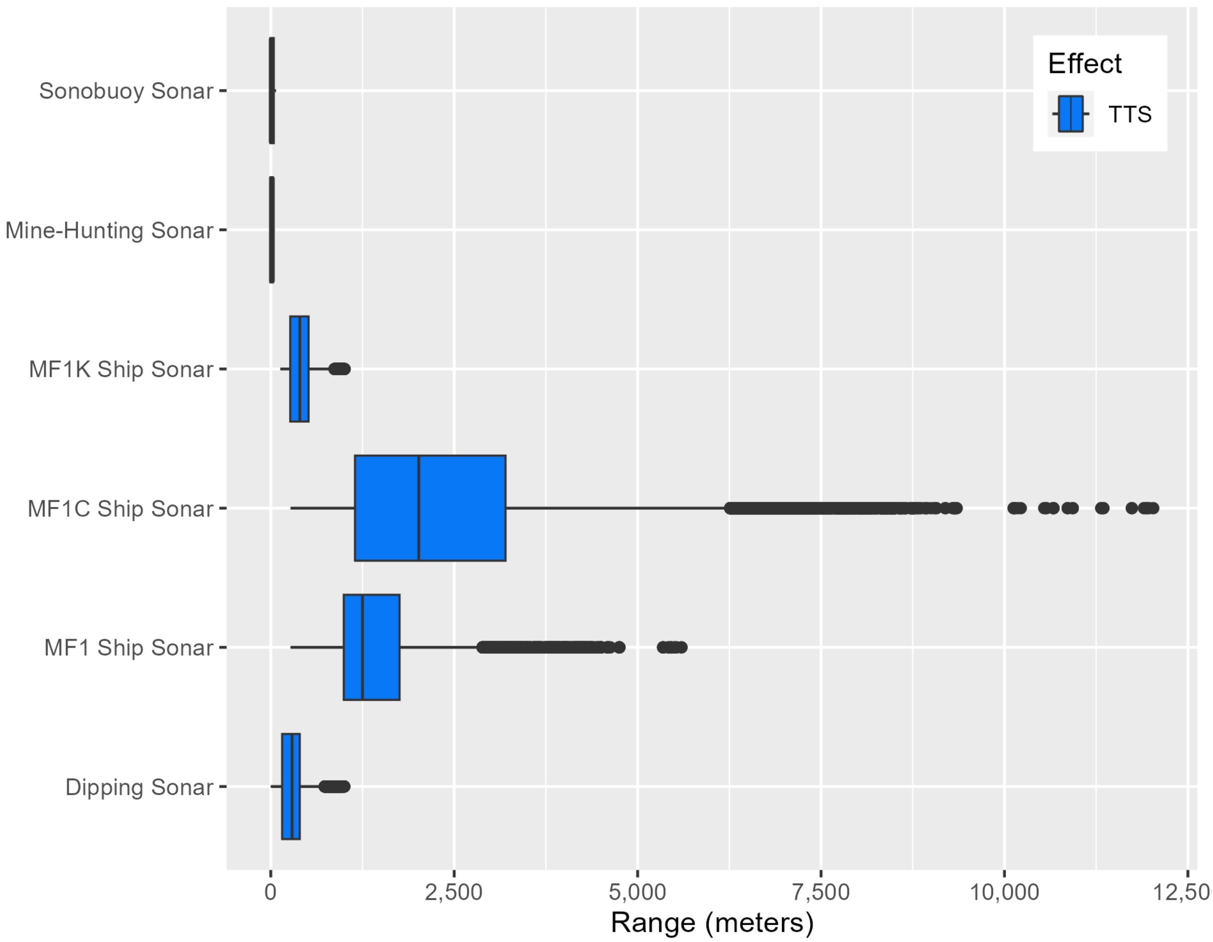

Figure 2.5-3: LF Cetacean Ranges to Temporary Threshold Shift for Sonar

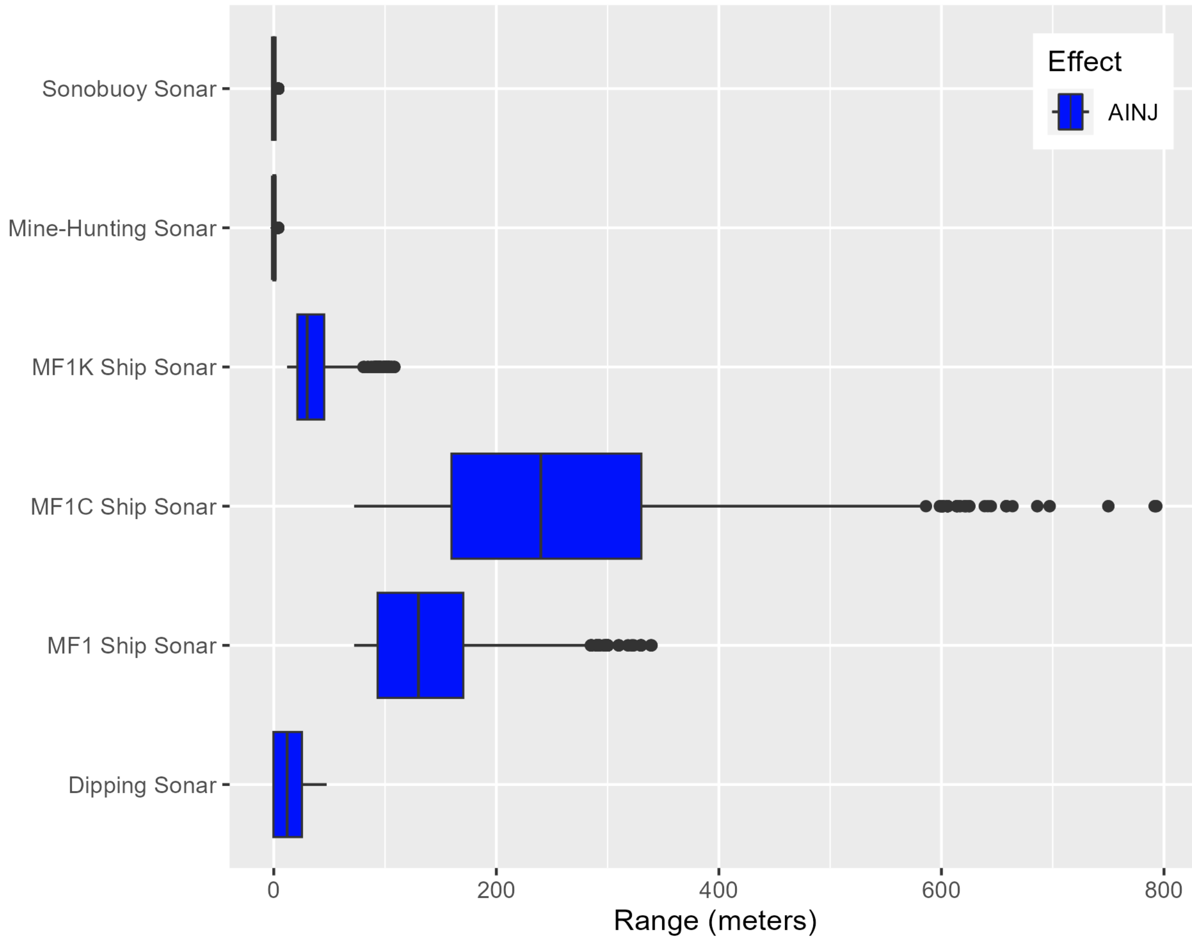

Figure 2.5-4: LF Cetacean Ranges to Auditory Injury for Sonar

Table 2.5-3: HF Cetacean Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	55 m (15 m)	5 m (2 m)
		30 s	120 m (33 m)	9 m (4 m)
		60 s	170 m (49 m)	12 m (5 m)
		120 s	252 m (84 m)	18 m (6 m)
	>200 m	1 s	50 m (28 m)	0 m (2 m)
		30 s	100 m (54 m)	0 m (4 m)
		60 s	130 m (74 m)	0 m (5 m)
		120 s	201 m (106 m)	0 m (8 m)
MF1 Ship Sonar	≤200 m	1 s	646 m (113 m)	45 m (7 m)
		30 s	646 m (113 m)	45 m (7 m)
		60 s	911 m (178 m)	65 m (12 m)
		120 s	1,014 m (244 m)	85 m (14 m)
	>200 m	1 s	600 m (55 m)	40 m (11 m)
		30 s	600 m (55 m)	40 m (11 m)
		60 s	875 m (97 m)	65 m (13 m)
		120 s	1,000 m (132 m)	85 m (7 m)
MF1C Ship Sonar	≤200 m	1 s	646 m (113 m)	45 m (7 m)
		30 s	1,014 m (244 m)	85 m (14 m)
		60 s	1,458 m (439 m)	130 m (24 m)
		120 s	1,889 m (735 m)	200 m (36 m)
	>200 m	1 s	600 m (55 m)	40 m (11 m)
		30 s	1,000 m (132 m)	85 m (7 m)
		60 s	1,500 m (306 m)	130 m (12 m)
		120 s	2,097 m (747 m)	200 m (18 m)
MF1K Ship Sonar	≤200 m	1 s	100 m (21 m)	7 m (3 m)
		30 s	190 m (34 m)	13 m (4 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	250 m (51 m)	17 m (5 m)
		120 s	363 m (72 m)	25 m (2 m)
	>200 m	1 s	100 m (18 m)	0 m (3 m)
		30 s	180 m (21 m)	11 m (6 m)
		60 s	240 m (29 m)	16 m (8 m)
		120 s	350 m (42 m)	24 m (11 m)
Mine-Hunting Sonar	≤200 m	1 s	8 m (3 m)	0 m (0 m)
		30 s	15 m (5 m)	1 m (0 m)
		60 s	21 m (6 m)	1 m (1 m)
		120 s	30 m (6 m)	2 m (1 m)
	>200 m	1 s	7 m (3 m)	0 m (0 m)
		30 s	15 m (6 m)	0 m (0 m)
		60 s	21 m (8 m)	0 m (1 m)
		120 s	30 m (5 m)	0 m (1 m)
Sonobuoy Sonar	≤200 m	1 s	8 m (4 m)	0 m (0 m)
		30 s	18 m (8 m)	0 m (0 m)
		60 s	25 m (12 m)	0 m (0 m)
		120 s	35 m (14 m)	0 m (1 m)
	>200 m	1 s	0 m (4 m)	0 m (0 m)
		30 s	0 m (9 m)	0 m (0 m)
		60 s	0 m (12 m)	0 m (0 m)
		120 s	30 m (16 m)	0 m (1 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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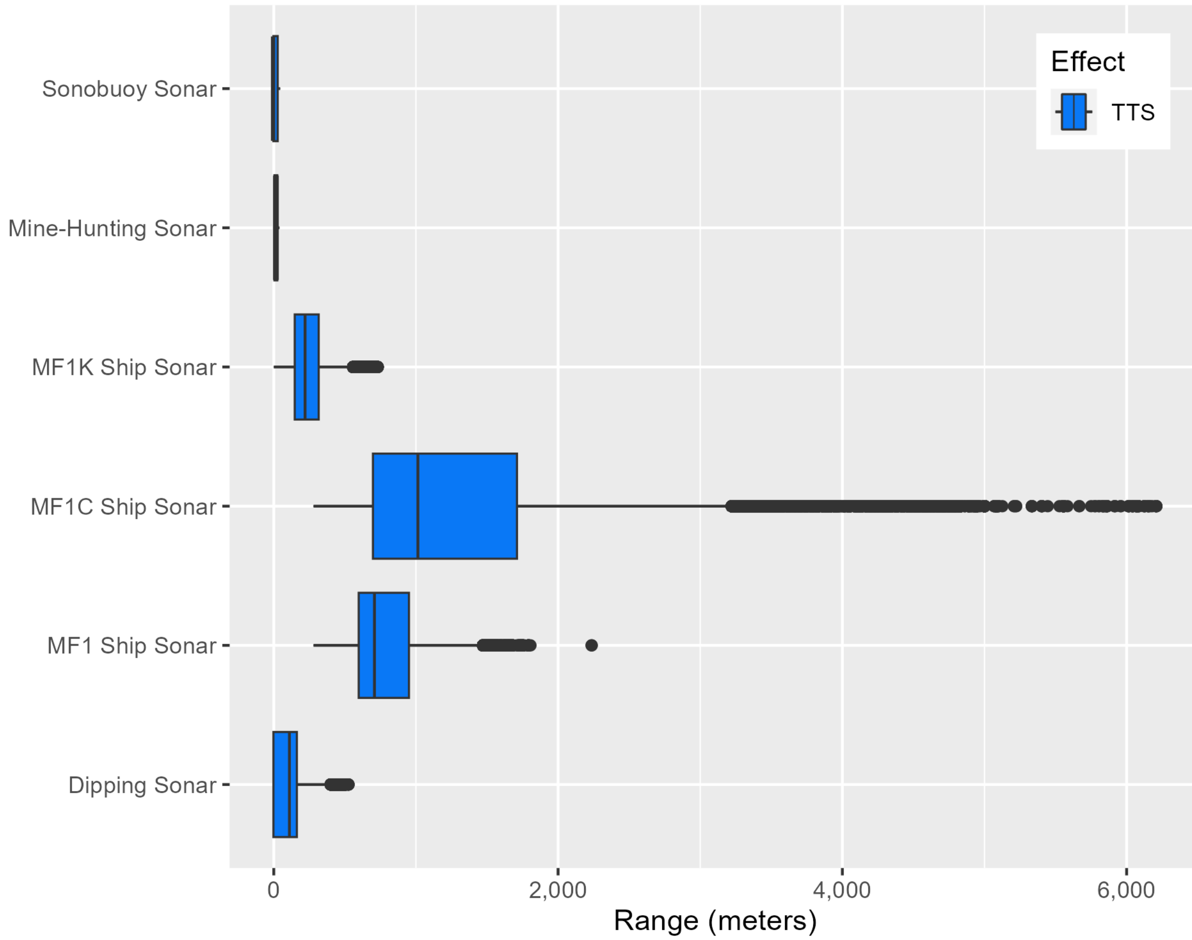

Figure 2.5-5: HF Cetacean Ranges to Temporary Threshold Shift for Sonar

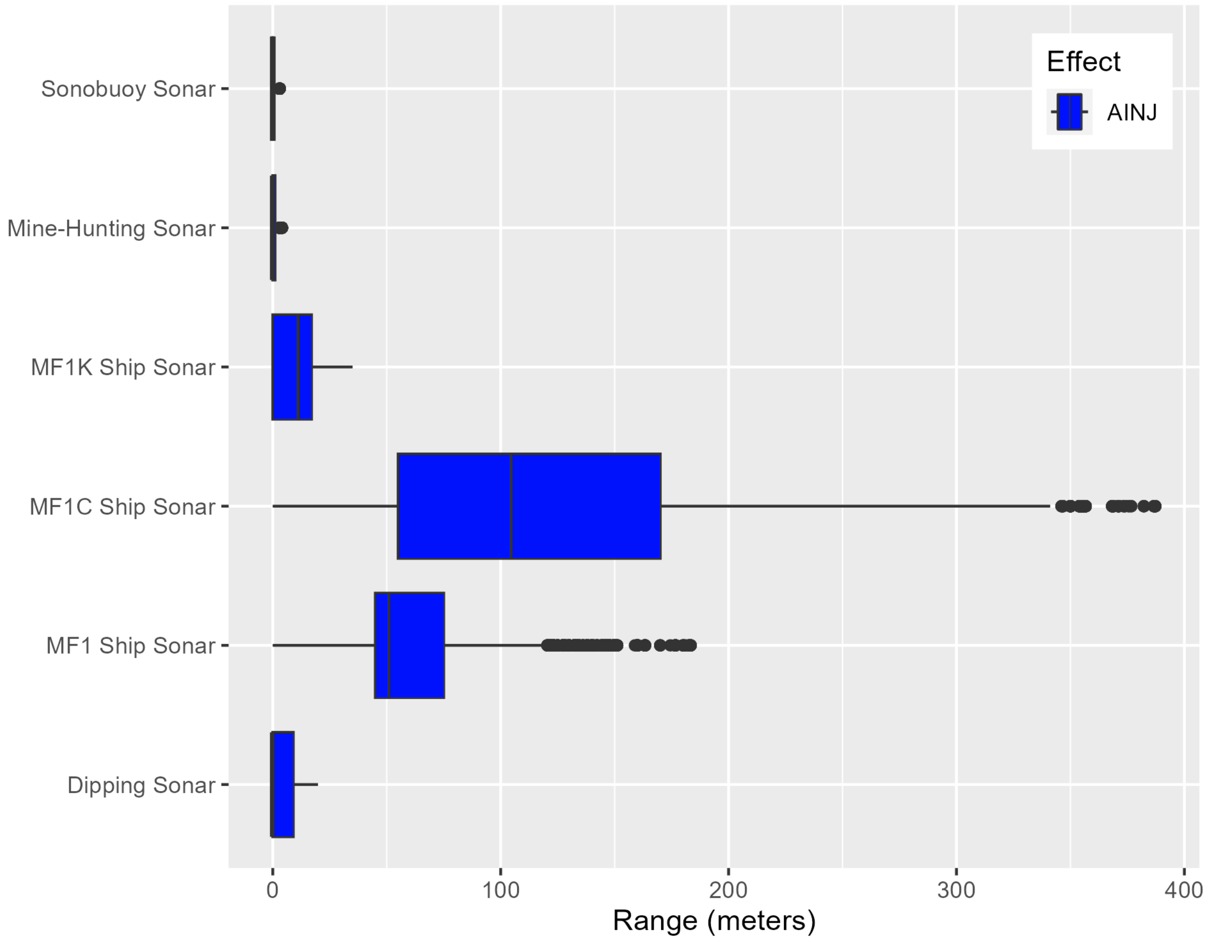

Figure 2.5-6: HF Cetacean Ranges to Auditory Injury for Sonar

Table 2.5-4: VHF Cetacean Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	100 m (29 m)	8 m (2 m)
		30 s	203 m (75 m)	14 m (4 m)
		60 s	280 m (91 m)	19 m (5 m)
		120 s	421 m (99 m)	25 m (6 m)
	>200 m	1 s	95 m (50 m)	0 m (3 m)
		30 s	180 m (101 m)	0 m (6 m)
		60 s	240 m (123 m)	14 m (8 m)
		120 s	330 m (86 m)	24 m (12 m)
MF1 Ship Sonar	≤200 m	1 s	1,514 m (471 m)	150 m (25 m)
		30 s	1,514 m (471 m)	150 m (25 m)
		60 s	1,986 m (759 m)	220 m (39 m)
		120 s	2,236 m (979 m)	280 m (57 m)
	>200 m	1 s	1,514 m (344 m)	150 m (13 m)
		30 s	1,514 m (344 m)	150 m (13 m)
		60 s	2,306 m (837 m)	220 m (22 m)
		120 s	2,819 m (1,098 m)	270 m (29 m)
MF1C Ship Sonar	≤200 m	1 s	1,514 m (471 m)	150 m (25 m)
		30 s	2,236 m (979 m)	280 m (57 m)
		60 s	2,703 m (1,382 m)	417 m (69 m)
		120 s	3,264 m (1,830 m)	592 m (100 m)
	>200 m	1 s	1,514 m (344 m)	150 m (13 m)
		30 s	2,819 m (1,098 m)	270 m (29 m)
		60 s	3,972 m (1,547 m)	390 m (31 m)
		120 s	5,792 m (2,220 m)	550 m (40 m)
MF1K Ship Sonar	≤200 m	1 s	315 m (60 m)	20 m (2 m)
		30 s	550 m (103 m)	35 m (5 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	712 m (139 m)	50 m (12 m)
		120 s	958 m (214 m)	85 m (12 m)
	>200 m	1 s	300 m (39 m)	16 m (3 m)
		30 s	525 m (46 m)	35 m (1 m)
		60 s	675 m (70 m)	50 m (2 m)
		120 s	957 m (120 m)	85 m (4 m)
Mine-Hunting Sonar	≤200 m	1 s	90 m (26 m)	9 m (1 m)
		30 s	190 m (85 m)	16 m (2 m)
		60 s	329 m (128 m)	22 m (2 m)
		120 s	521 m (166 m)	30 m (3 m)
	>200 m	1 s	90 m (6 m)	7 m (1 m)
		30 s	150 m (31 m)	15 m (0 m)
		60 s	210 m (59 m)	22 m (0 m)
		120 s	300 m (82 m)	30 m (0 m)
Sonobuoy Sonar	≤200 m	1 s	65 m (20 m)	0 m (2 m)
		30 s	126 m (39 m)	9 m (5 m)
		60 s	191 m (79 m)	15 m (5 m)
		120 s	314 m (120 m)	22 m (7 m)
	>200 m	1 s	65 m (31 m)	0 m (1 m)
		30 s	110 m (59 m)	0 m (4 m)
		60 s	178 m (76 m)	10 m (7 m)
		120 s	280 m (75 m)	21 m (10 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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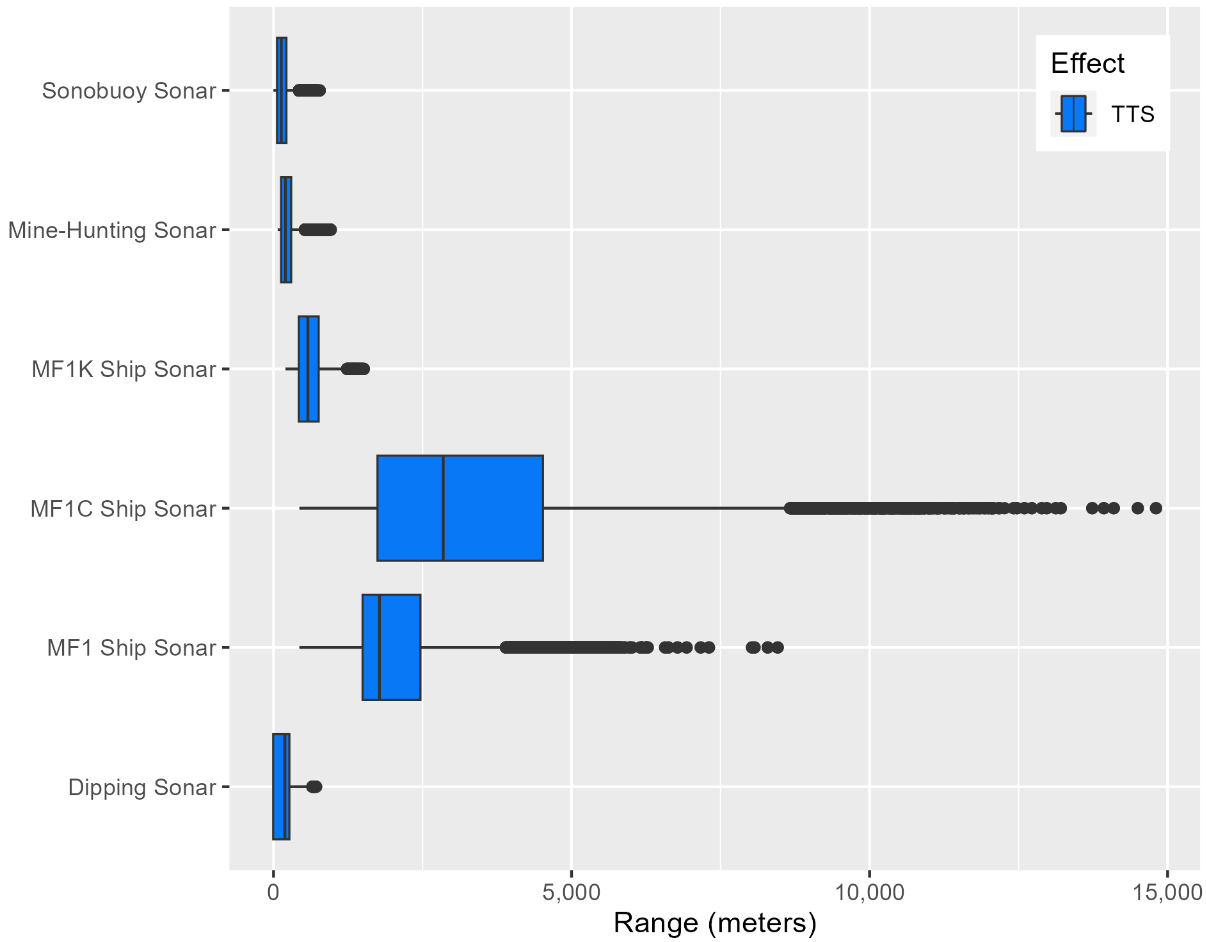

Figure 2.5-7: VHF Cetacean Ranges to Temporary Threshold Shift for Sonar

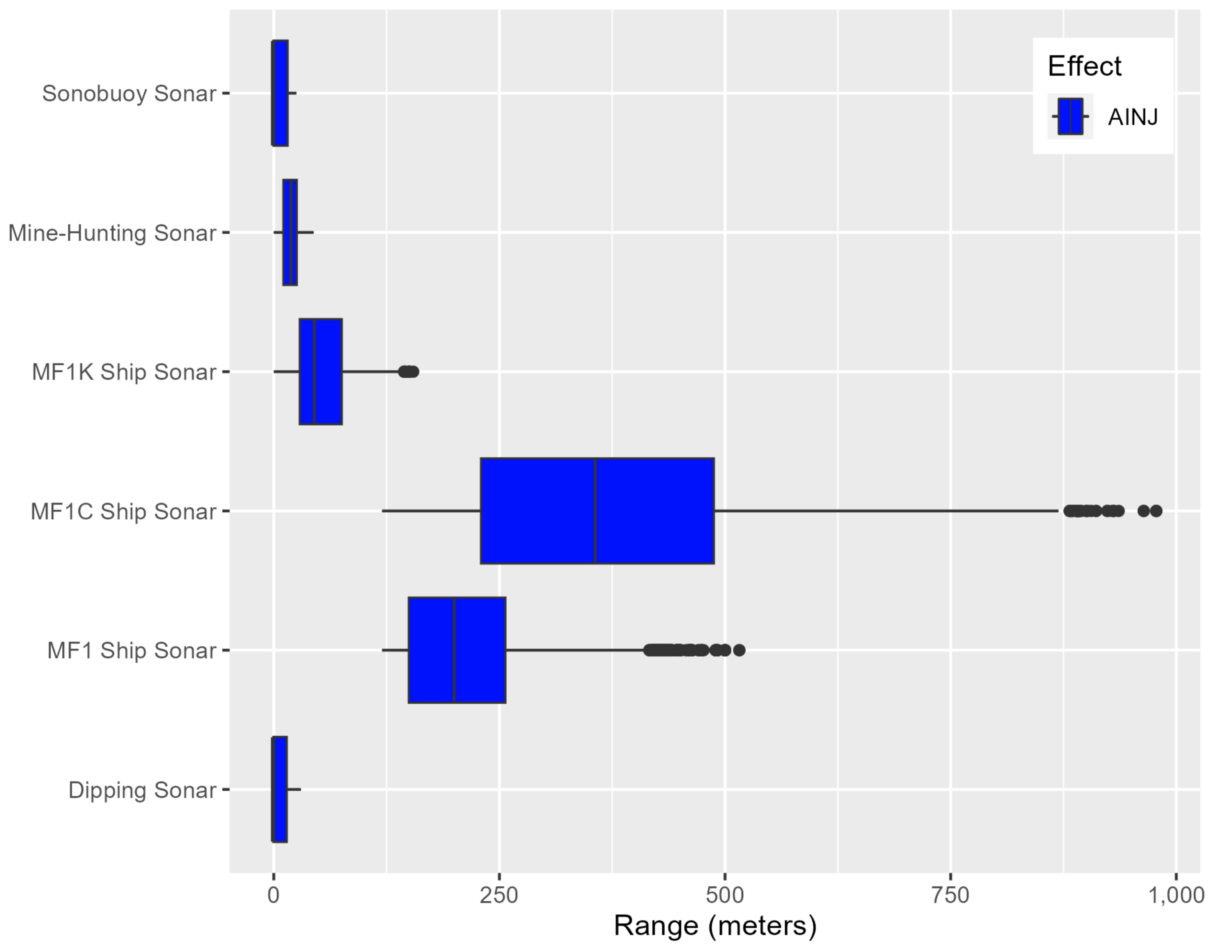

Figure 2.5-8: VHF Cetacean Ranges to Auditory Injury for Sonar

Table 2.5-5: Phocids in Water Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	200 m (50 m)	0 m (7 m)
		30 s	372 m (98 m)	22 m (12 m)
		60 s	497 m (130 m)	30 m (15 m)
		120 s	708 m (144 m)	45 m (12 m)
	>200 m	1 s	160 m (71 m)	0 m (4 m)
		30 s	298 m (130 m)	0 m (8 m)
		60 s	370 m (171 m)	0 m (10 m)
		120 s	550 m (81 m)	0 m (19 m)
MF1 Ship Sonar	≤200 m	1 s	1,250 m (386 m)	120 m (20 m)
		30 s	1,250 m (386 m)	120 m (20 m)
		60 s	1,625 m (635 m)	180 m (33 m)
		120 s	1,861 m (838 m)	230 m (45 m)
	>200 m	1 s	1,250 m (289 m)	120 m (53 m)
		30 s	1,250 m (289 m)	120 m (53 m)
		60 s	1,750 m (672 m)	180 m (21 m)
		120 s	2,250 m (939 m)	220 m (23 m)
MF1C Ship Sonar	≤200 m	1 s	1,250 m (386 m)	120 m (20 m)
		30 s	1,861 m (838 m)	230 m (45 m)
		60 s	2,319 m (1,230 m)	330 m (74 m)
		120 s	2,799 m (1,642 m)	484 m (98 m)
	>200 m	1 s	1,250 m (289 m)	120 m (53 m)
		30 s	2,250 m (939 m)	220 m (23 m)
		60 s	3,306 m (1,352 m)	320 m (32 m)
		120 s	4,486 m (1,866 m)	460 m (47 m)
MF1K Ship Sonar	≤200 m	1 s	248 m (58 m)	0 m (9 m)
		30 s	435 m (97 m)	25 m (8 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	550 m (133 m)	35 m (10 m)
		120 s	771 m (190 m)	65 m (14 m)
	>200 m	1 s	240 m (27 m)	0 m (8 m)
		30 s	430 m (51 m)	24 m (13 m)
		60 s	550 m (64 m)	35 m (16 m)
		120 s	775 m (108 m)	65 m (28 m)
Mine-Hunting Sonar	≤200 m	1 s	12 m (7 m)	0 m (0 m)
		30 s	24 m (11 m)	0 m (1 m)
		60 s	35 m (11 m)	0 m (1 m)
		120 s	50 m (15 m)	0 m (2 m)
	>200 m	1 s	0 m (5 m)	0 m (0 m)
		30 s	22 m (9 m)	0 m (0 m)
		60 s	30 m (4 m)	0 m (1 m)
		120 s	45 m (5 m)	0 m (1 m)
Sonobuoy Sonar	≤200 m	1 s	0 m (11 m)	0 m (0 m)
		30 s	35 m (16 m)	0 m (1 m)
		60 s	50 m (19 m)	0 m (1 m)
		120 s	75 m (20 m)	0 m (3 m)
	>200 m	1 s	0 m (7 m)	0 m (0 m)
		30 s	0 m (16 m)	0 m (0 m)
		60 s	45 m (23 m)	0 m (0 m)
		120 s	70 m (32 m)	0 m (1 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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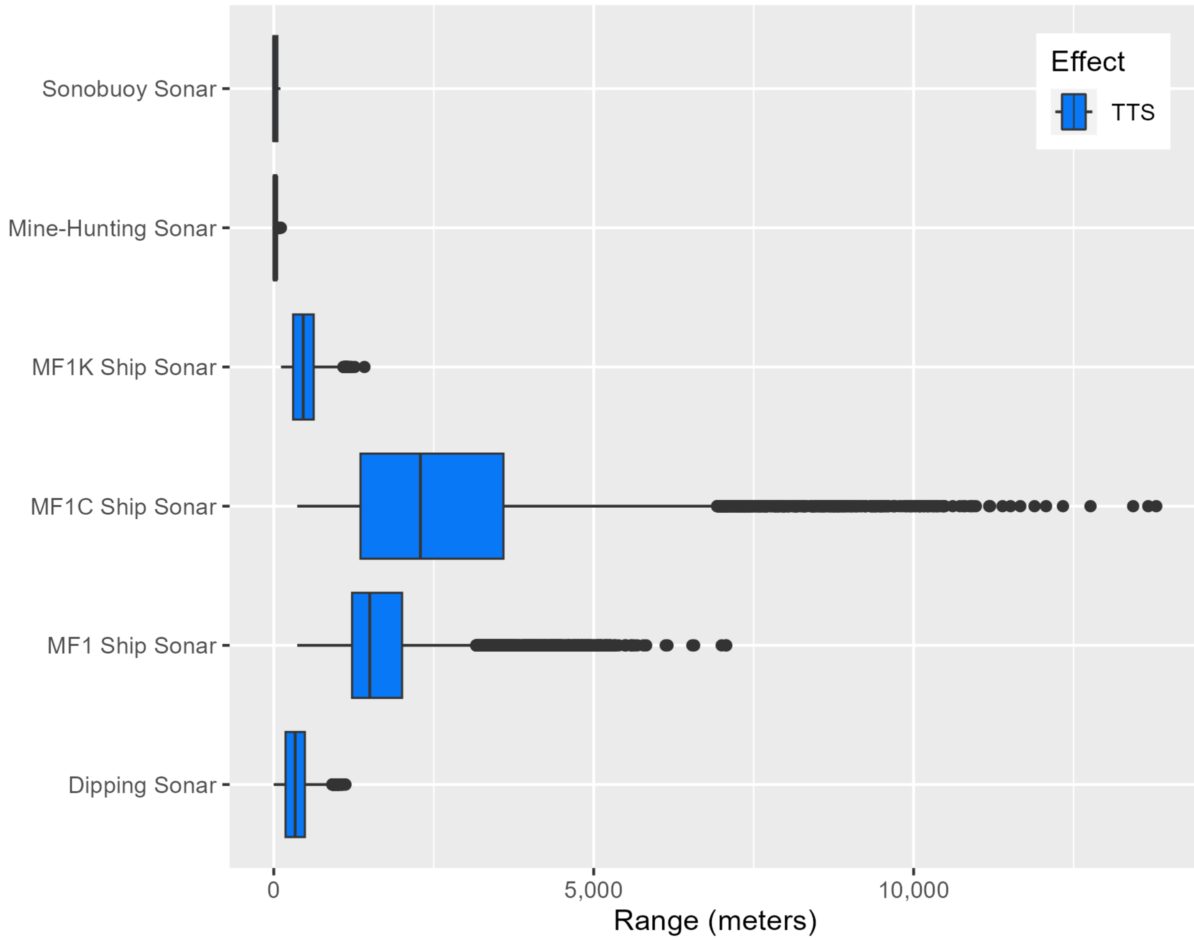

Figure 2.5-9: Phocids in Water Ranges to Temporary Threshold Shift for Sonar

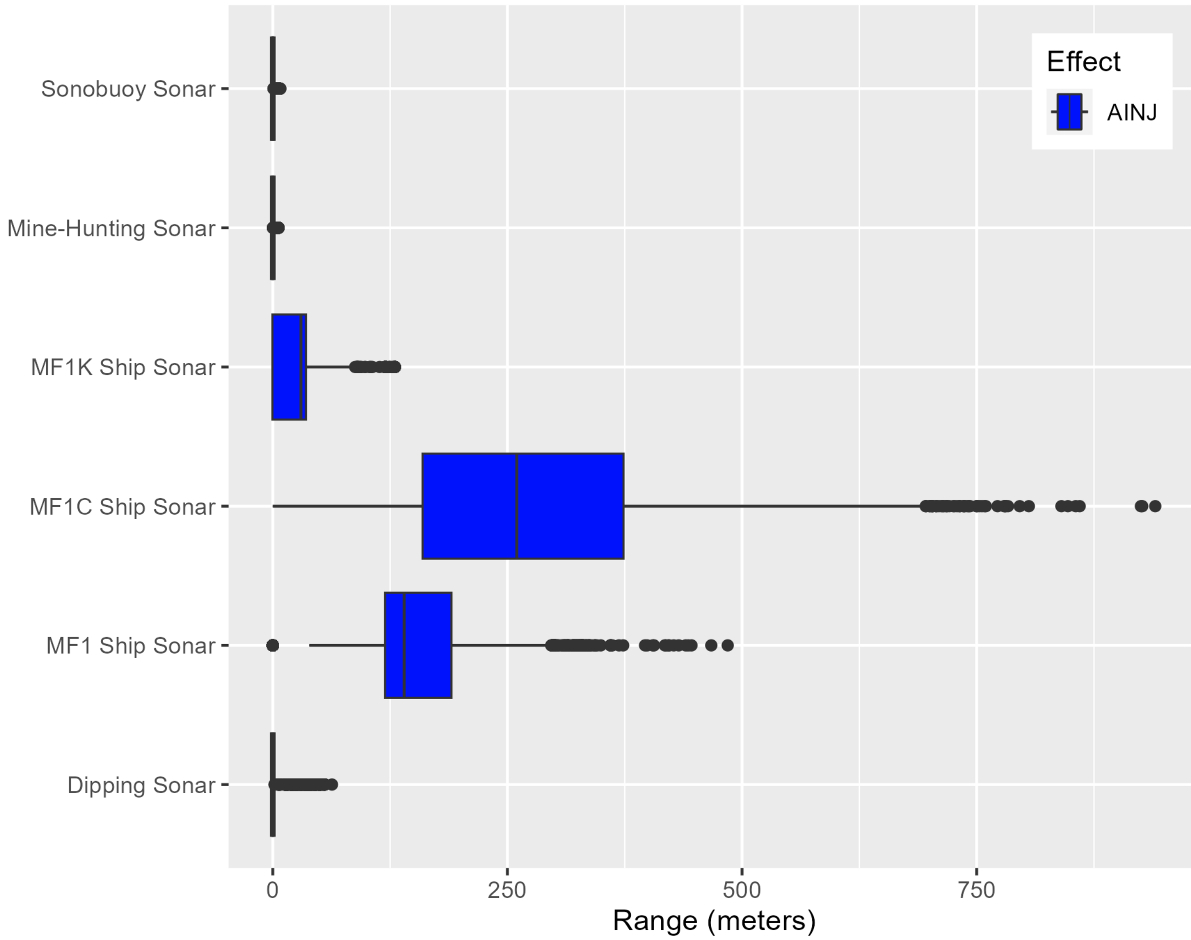

Figure 2.5-10: Phocids in Water Ranges to Auditory Injury for Sonar

Table 2.5-6: Otariids in Water Ranges to Effects for Sonar

Sonar Type	Depth	Duration	TTS	AINJ
Dipping Sonar	≤200 m	1 s	60 m (15 m)	0 m (3 m)
		30 s	130 m (37 m)	0 m (5 m)
		60 s	180 m (55 m)	0 m (6 m)
		120 s	277 m (84 m)	14 m (9 m)
	>200 m	1 s	55 m (31 m)	0 m (2 m)
		30 s	120 m (66 m)	0 m (4 m)
		60 s	160 m (90 m)	0 m (5 m)
		120 s	210 m (117 m)	0 m (8 m)
MF1 Ship Sonar	≤200 m	1 s	731 m (149 m)	50 m (10 m)
		30 s	731 m (149 m)	50 m (10 m)
		60 s	981 m (221 m)	80 m (12 m)
		120 s	1,139 m (297 m)	110 m (19 m)
	>200 m	1 s	725 m (98 m)	50 m (1 m)
		30 s	725 m (98 m)	50 m (1 m)
		60 s	1,000 m (163 m)	80 m (5 m)
		120 s	1,250 m (256 m)	100 m (8 m)
MF1C Ship Sonar	≤200 m	1 s	731 m (149 m)	50 m (10 m)
		30 s	1,139 m (297 m)	110 m (19 m)
		60 s	1,493 m (462 m)	160 m (23 m)
		120 s	1,847 m (691 m)	240 m (40 m)
	>200 m	1 s	725 m (98 m)	50 m (1 m)
		30 s	1,250 m (256 m)	100 m (8 m)
		60 s	1,653 m (527 m)	160 m (13 m)
		120 s	2,222 m (1,019 m)	240 m (23 m)
MF1K Ship Sonar	≤200 m	1 s	120 m (22 m)	8 m (4 m)
		30 s	230 m (40 m)	16 m (4 m)

Sonar Type	Depth	Duration	TTS	AINJ
		60 s	300 m (56 m)	20 m (3 m)
		120 s	426 m (77 m)	25 m (4 m)
	>200 m	1 s	120 m (12 m)	0 m (4 m)
		30 s	220 m (31 m)	14 m (6 m)
		60 s	290 m (40 m)	20 m (5 m)
		120 s	420 m (60 m)	25 m (1 m)
Mine-Hunting Sonar	≤200 m	1 s	6 m (3 m)	0 m (0 m)
		30 s	11 m (6 m)	0 m (0 m)
		60 s	18 m (8 m)	0 m (0 m)
		120 s	25 m (10 m)	0 m (1 m)
	>200 m	1 s	6 m (3 m)	0 m (0 m)
		30 s	11 m (5 m)	0 m (0 m)
		60 s	18 m (7 m)	0 m (0 m)
		120 s	25 m (10 m)	0 m (1 m)
Sonobuoy Sonar	≤200 m	1 s	0 m (6 m)	0 m (0 m)
		30 s	18 m (11 m)	0 m (0 m)
		60 s	30 m (13 m)	0 m (1 m)
		120 s	45 m (20 m)	0 m (1 m)
	>200 m	1 s	0 m (5 m)	0 m (0 m)
		30 s	0 m (11 m)	0 m (0 m)
		60 s	25 m (14 m)	0 m (0 m)
		120 s	40 m (22 m)	0 m (1 m)

Median ranges with standard deviation ranges in parentheses
TTS = Temporary Threshold Shift, AINJ = Auditory Injury
MF1 = hull-mounted surface ship sonar, MF1C = >80% duty cycle, MF1K = kingfisher mode
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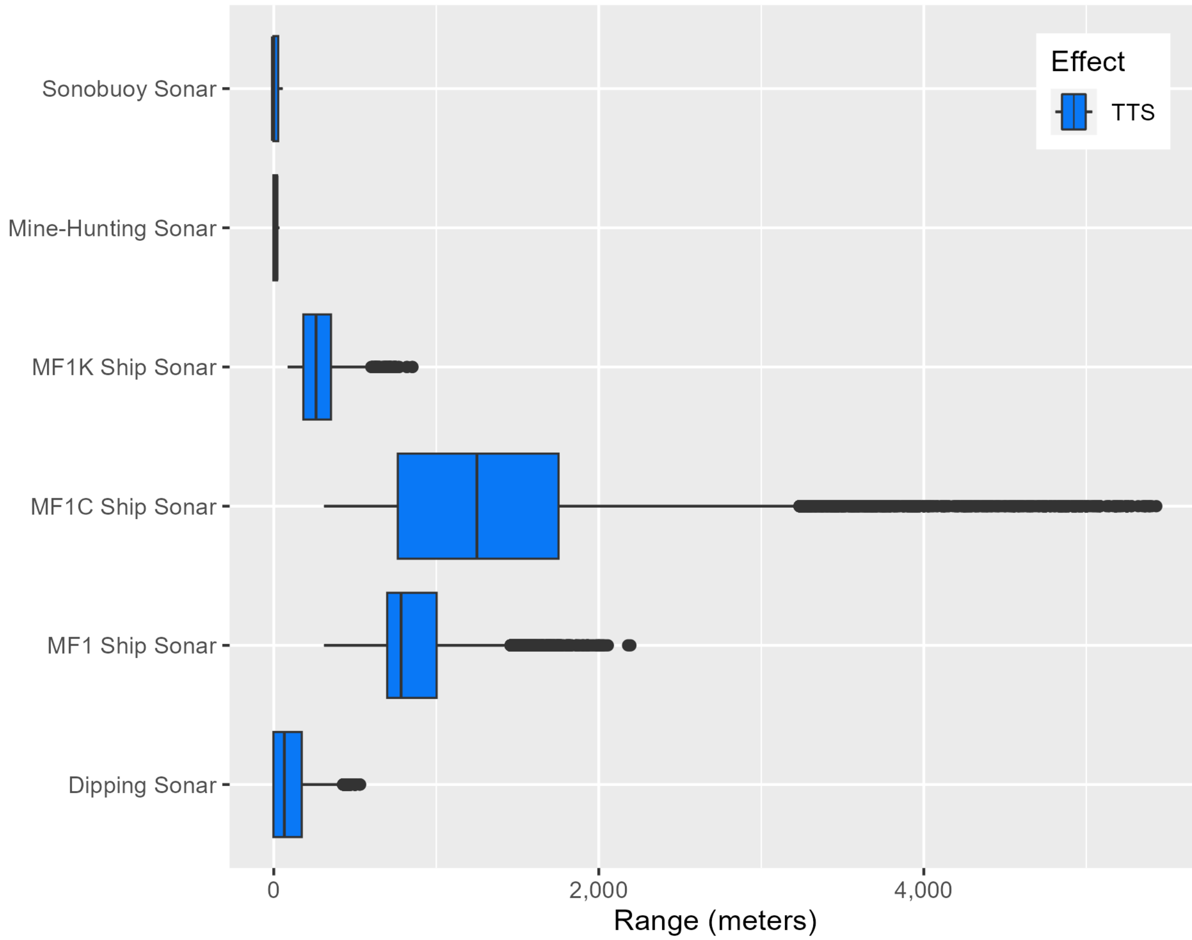

Figure 2.5-11: Otariids in Water Ranges to Temporary Threshold Shift for Sonar

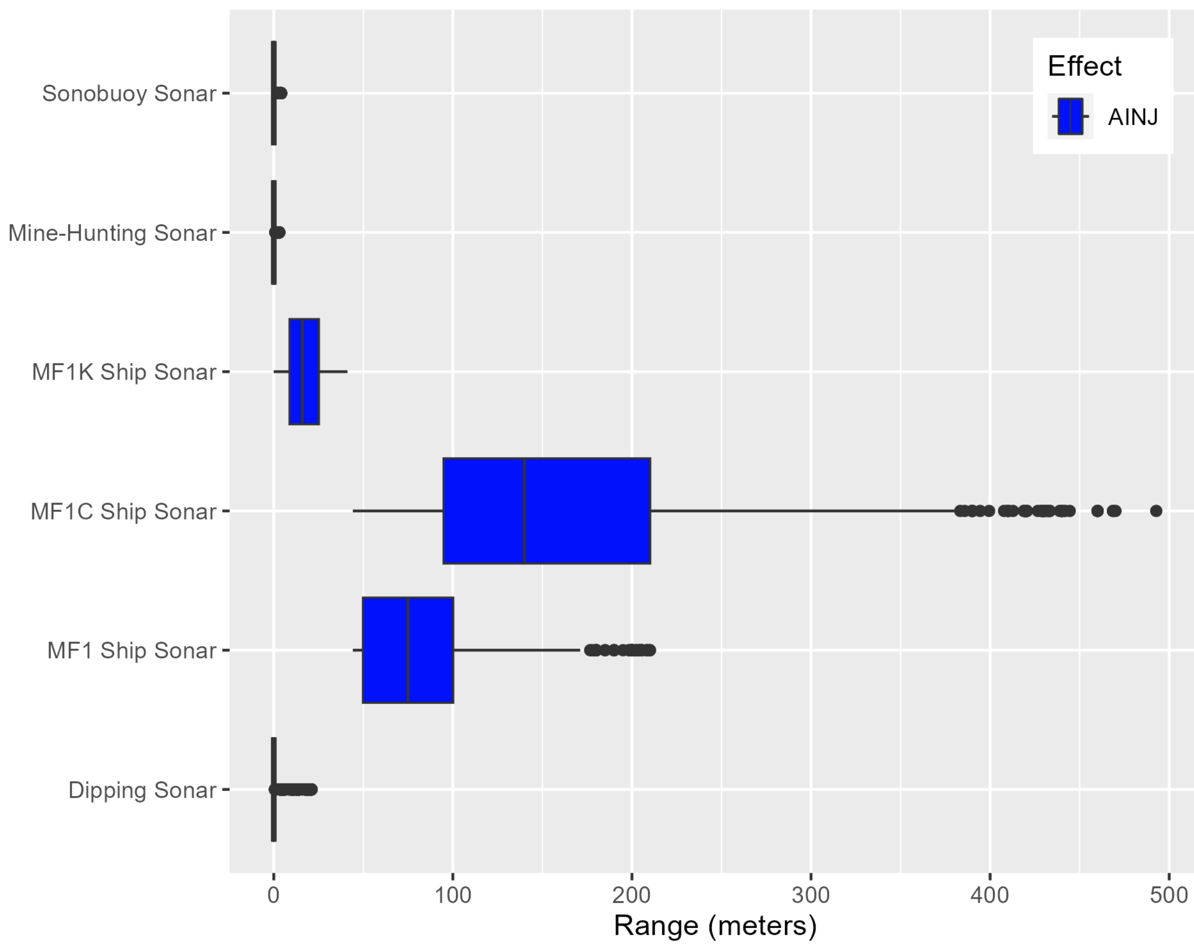

Figure 2.5-12: Otariids in Water Ranges to Auditory Injury for Sonar

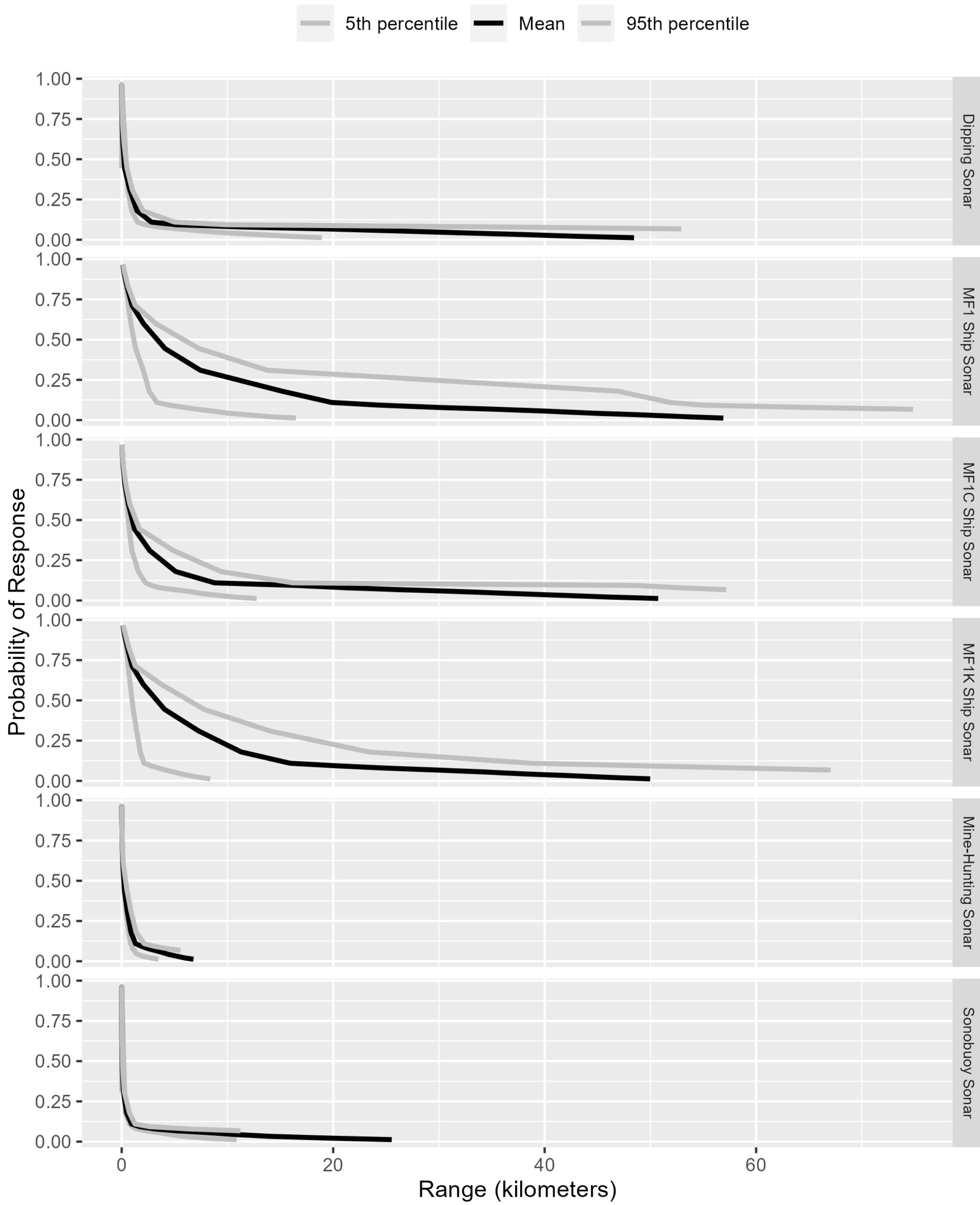

Figure 2.5-13: Probability of Behavioral Response to Sonar as a Function of Range for Odontocetes

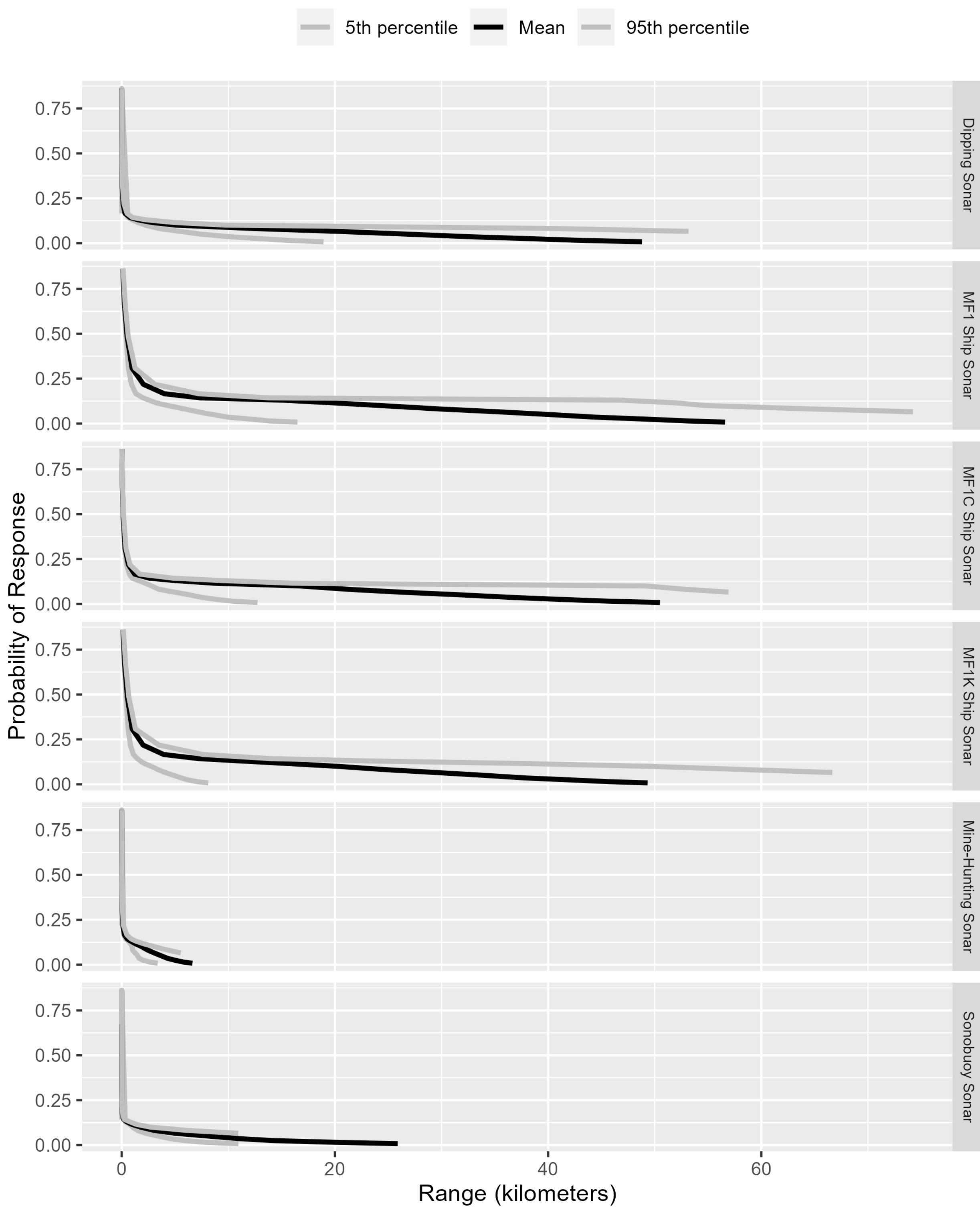

Figure 2.5-14: Probability of Behavioral Response to Sonar as a Function of Range for Mysticetes

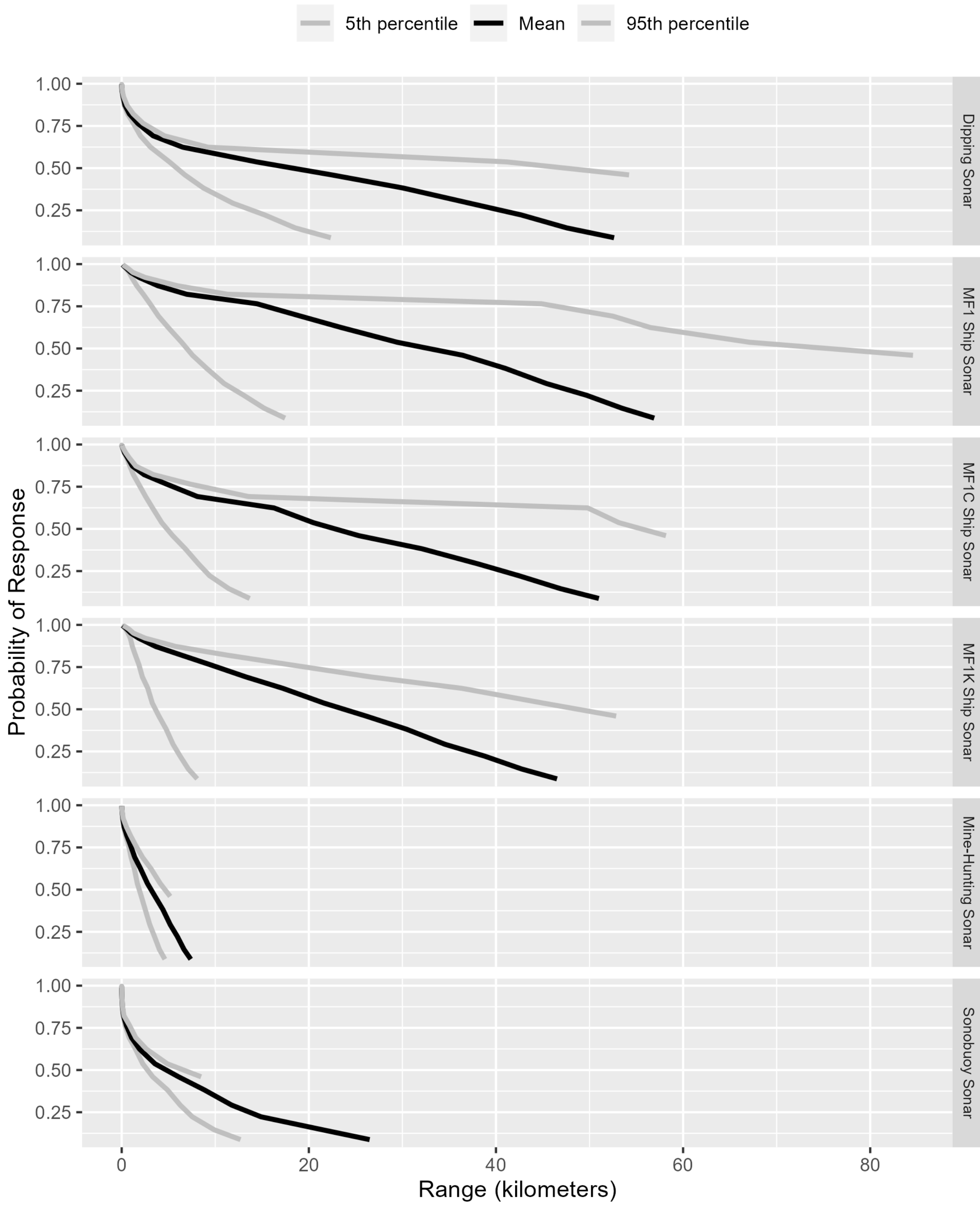

Figure 2.5-15: Probability of Behavioral Response to Sonar as a Function of Range for Sensitive Species

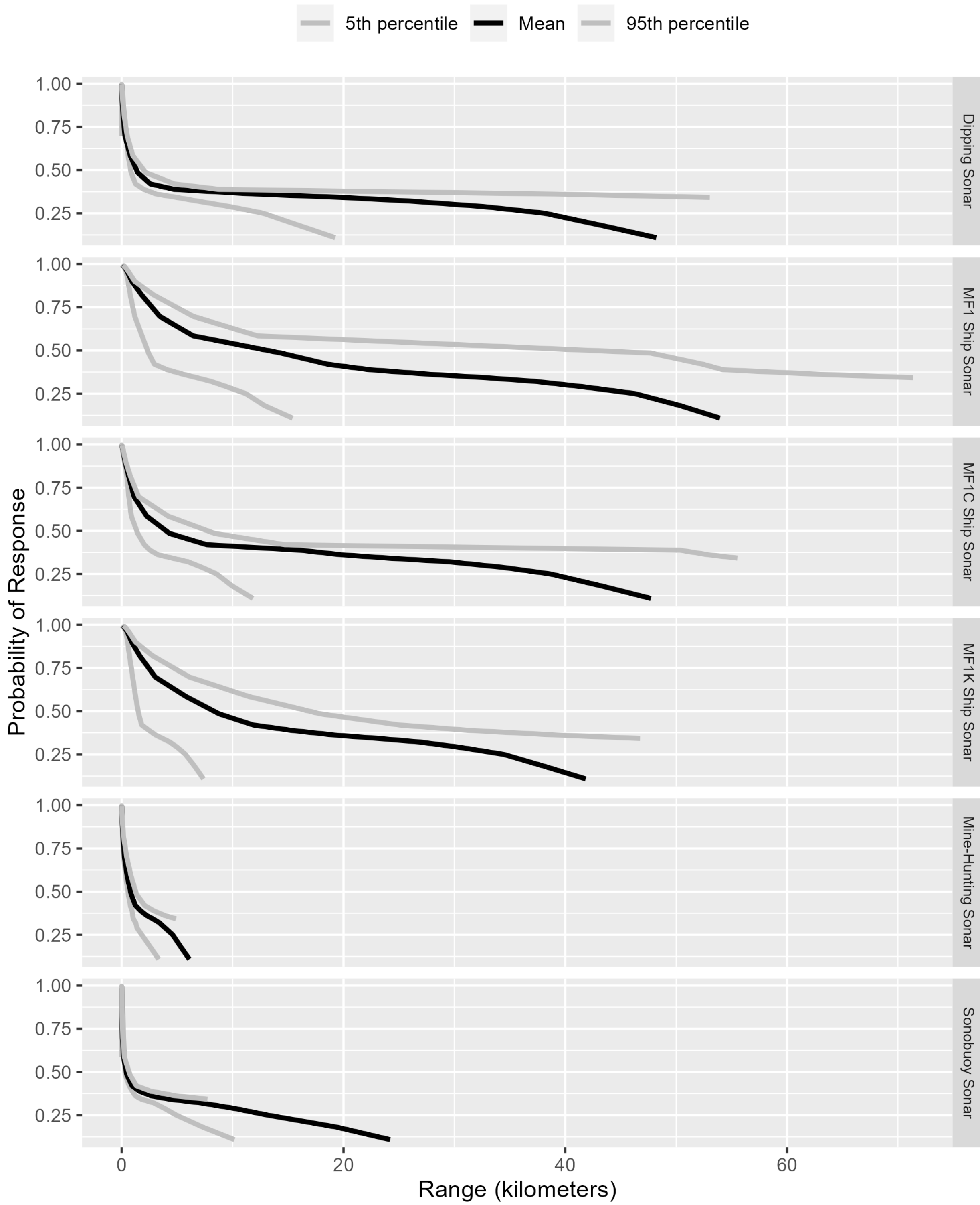

Figure 2.5-16: Probability of Behavioral Response to Sonar as a Function of Range for Pinnipeds

2.5.2 Ranges to Effects for Air Guns

Ranges to effects for air guns were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a hearing group that would cause behavioral response, TTS, and AINJ, as described in the *Criteria and Thresholds TR*. The air gun ranges to effects for TTS and AINJ that are in the tables are based on the metric (i.e., SEL or SPL) that produced longer ranges.

Table 2.5-7: VLF Cetacean Ranges to Effects for Air Guns

Bin	Depth	Cluster Size	BEH	TTS	AINJ
Air Gun	≤200 m	1	NA	5 m (0 m)	1 m (1 m)
		10	113 m (6 m)	81 m (1 m)	14 m (0 m)
	>200 m	1	NA	5 m (0 m)	1 m (1 m)
		10	114 m (6 m)	81 m (1 m)	14 m (0 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
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Table 2.5-8: LF Cetacean Ranges to Effects for Air Guns

Bin	Depth	Cluster Size	BEH	TTS	AINJ
Air Gun	≤200 m	1	NA	5 m (0 m)	2 m (0 m)
		10	104 m (6 m)	36 m (0 m)	6 m (0 m)
	>200 m	1	NA	5 m (0 m)	2 m (0 m)
		10	107 m (7 m)	35 m (0 m)	6 m (0 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
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Table 2.5-9: HF Cetacean Ranges to Effects for Air Guns

Bin	Depth	Cluster Size	BEH	TTS	AINJ
Air Gun	≤200 m	1	NA	2 m (1 m)	0 m (0 m)
		10	108 m (6 m)	2 m (1 m)	0 m (0 m)
	>200 m	1	NA	2 m (1 m)	0 m (0 m)
		10	112 m (7 m)	2 m (1 m)	0 m (0 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
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Table 2.5-10: VHF Cetacean Ranges to Effects for Air Guns

Bin	Depth	Cluster Size	BEH	TTS	AINJ
Air Gun	≤200 m	1	NA	51 m (1 m)	25 m (0 m)
		10	108 m (6 m)	51 m (1 m)	25 m (0 m)
	>200 m	1	NA	50 m (1 m)	25 m (0 m)
		10	113 m (7 m)	50 m (1 m)	25 m (0 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
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2.5.3 Ranges to Effects for Pile Driving

Table 2.5-11 shows the predicted ranges to AINJ, TTS, and behavioral response for each marine mammal hearing group exposed to impact and vibratory pile driving. These ranges were estimated based on activity parameters described in the *Acoustic Stressors* section and using the calculations described in the *Quantitative Analysis TR.*

Table 2.5-11: Marine Mammal Ranges to Effects for Pile Driving

FHG	Pile Type/Size and Method	BEH	TTS	AINJ
OCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	43 m	4 m
	20" Steel H Piles using Impact Methods	215 m	201 m	20 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	685 m	69 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	3,981 m	12 m	1 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	3,981 m	36 m	2 m
PCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	116 m	12 m
	20" Steel H Piles using Impact Methods	215 m	538 m	54 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	1,839 m	184 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	11,659 m	35 m	2 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	11,659 m	105 m	5 m

Note: AINJ = auditory injury, TTS = temporary threshold shift, BEH = behavior, OCW = otariids in water, PCW = phocids in water

2.5.4 Ranges to Effects for Explosives

Ranges to effects for explosives were determined by modeling the distance that noise from an explosion would need to propagate to reach exposure level thresholds specific to a hearing group that would cause behavioral response, TTS, AINJ, non-auditory injury, and mortality, as described in the *Criteria and Thresholds TR*.

The Navy Acoustic Effects Model cannot account for the highly non-linear effects of cavitation and surface blow off for shallow underwater explosions, nor can it estimate the explosive energy entering the water from a low-altitude detonation. Thus, for this analysis, in-air sources detonating at or near (within 10 m) the surface are modeled as if detonating completely underwater at a source depth of 0.1 m, with all energy reflected into the water rather than released into the air. Therefore, the amount of explosive and acoustic energy entering the water, and consequently the estimated ranges to effects, are likely to be overestimated. In the tables below, near surface explosions can occur for bathymetric depth intervals of ≤200 m and >200 m.

The tables below provide the ranges for a representative cluster size for each bin. Ranges for behavioral response are only provided if more than one explosive cluster occurs. Single explosions at received sound levels below TTS and AINJ thresholds are most likely to result in a brief alerting or orienting response. Due to the lack of subsequent explosions, a significant behavioral response is not expected for a single explosive cluster. For events with multiple explosions, sound from successive explosions can be expected to accumulate and increase the range to the onset of an impact based on SEL thresholds. Modeled ranges to TTS and AINJ based on peak pressure for a single explosion generally exceed the modeled ranges based on SEL even when accumulated for multiple explosions. Peak pressure-based ranges are estimated using the best available science; however, data on peak pressure at far distances from explosions are very limited. The explosive ranges to effects for TTS and AINJ that are in the tables are based on the metric (i.e., SEL or SPL) that produced longer ranges.

For non-auditory injury in the tables, the larger of the range to slight lung injury or gastrointestinal tract injury was used as a conservative estimate, and the boxplots present ranges for both metrics for comparison. Since the non-auditory metric is SPL-based, ranges are only available for a cluster size of one. Animals within water volumes encompassing the estimated range to non-auditory injury would be expected to receive minor injuries at the outer ranges, increasing to more substantial injuries, and finally mortality as an animal approaches the detonation point.

Table 2.5-12: VLF Cetacean Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	201 m (72 m)	96 m (2 m)
		5	627 m (231 m)	390 m (164 m)	96 m (2 m)
		25	1,262 m (443 m)	798 m (266 m)	180 m (62 m)
		50	1,419 m (471 m)	800 m (178 m)	250 m (34 m)
	>200 m	1	NA	220 m (55 m)	96 m (2 m)
		5	603 m (58 m)	430 m (17 m)	96 m (2 m)
		25	950 m (152 m)	700 m (81 m)	190 m (5 m)
		50	1,000 m (296 m)	850 m (89 m)	270 m (5 m)
E2	≤200 m	1	NA	359 m (40 m)	130 m (11 m)
	>200 m	1	NA	369 m (44 m)	131 m (12 m)
E3	≤200 m	1	NA	484 m (367 m)	213 m (7 m)
		5	1,542 m (616 m)	919 m (370 m)	213 m (7 m)
		25	2,703 m (1,191 m)	1,740 m (690 m)	421 m (181 m)
	>200 m	1	NA	825 m (305 m)	218 m (6 m)
		5	1,000 m (330 m)	750 m (144 m)	220 m (5 m)
		25	1,812 m (1,028 m)	1,000 m (366 m)	420 m (15 m)
E4	≤200 m	1	NA	1,903 m (777 m)	375 m (21 m)
	>200 m	1	NA	1,292 m (277 m)	370 m (24 m)
E5	≤200 m	1	NA	833 m (862 m)	358 m (25 m)
		5	2,956 m (1,325 m)	1,597 m (723 m)	358 m (25 m)
	>200 m	1	NA	650 m (146 m)	344 m (22 m)
		5	2,208 m (988 m)	1,056 m (443 m)	350 m (53 m)
		20	3,965 m (992 m)	2,486 m (578 m)	575 m (170 m)
E6	≤200 m	1	NA	1,868 m (1,345 m)	547 m (386 m)
		15	7,258 m (1,106 m)	5,397 m (814 m)	2,029 m (104 m)
	>200 m	1	NA	1,514 m (792 m)	512 m (44 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E7	≤200 m	1	NA	1,658 m (738 m)	538 m (23 m)
	>200 m	1	NA	1,500 m (1,296 m)	538 m (22 m)
E8	≤200 m	1	NA	2,555 m (414 m)	773 m (51 m)
	>200 m	1	NA	2,503 m (398 m)	764 m (48 m)
E9	≤200 m	1	NA	3,375 m (1,548 m)	757 m (48 m)
	>200 m	1	NA	2,722 m (1,222 m)	758 m (48 m)
E10	≤200 m	1	NA	4,243 m (722 m)	893 m (80 m)
	>200 m	1	NA	4,174 m (754 m)	892 m (94 m)
E11	≤200 m	1	NA	17,083 m (3,549 m)	1,799 m (57 m)
	>200 m	1	NA	15,833 m (3,966 m)	1,833 m (111 m)
E12	≤200 m	1	NA	4,507 m (633 m)	992 m (79 m)
	>200 m	1	NA	4,361 m (691 m)	1,012 m (85 m)
E13	≤200 m	1	NA	7,208 m (5,750 m)	3,361 m (1,875 m)
E16	>200 m	1	NA	10,778 m (8,250 m)	2,438 m (65 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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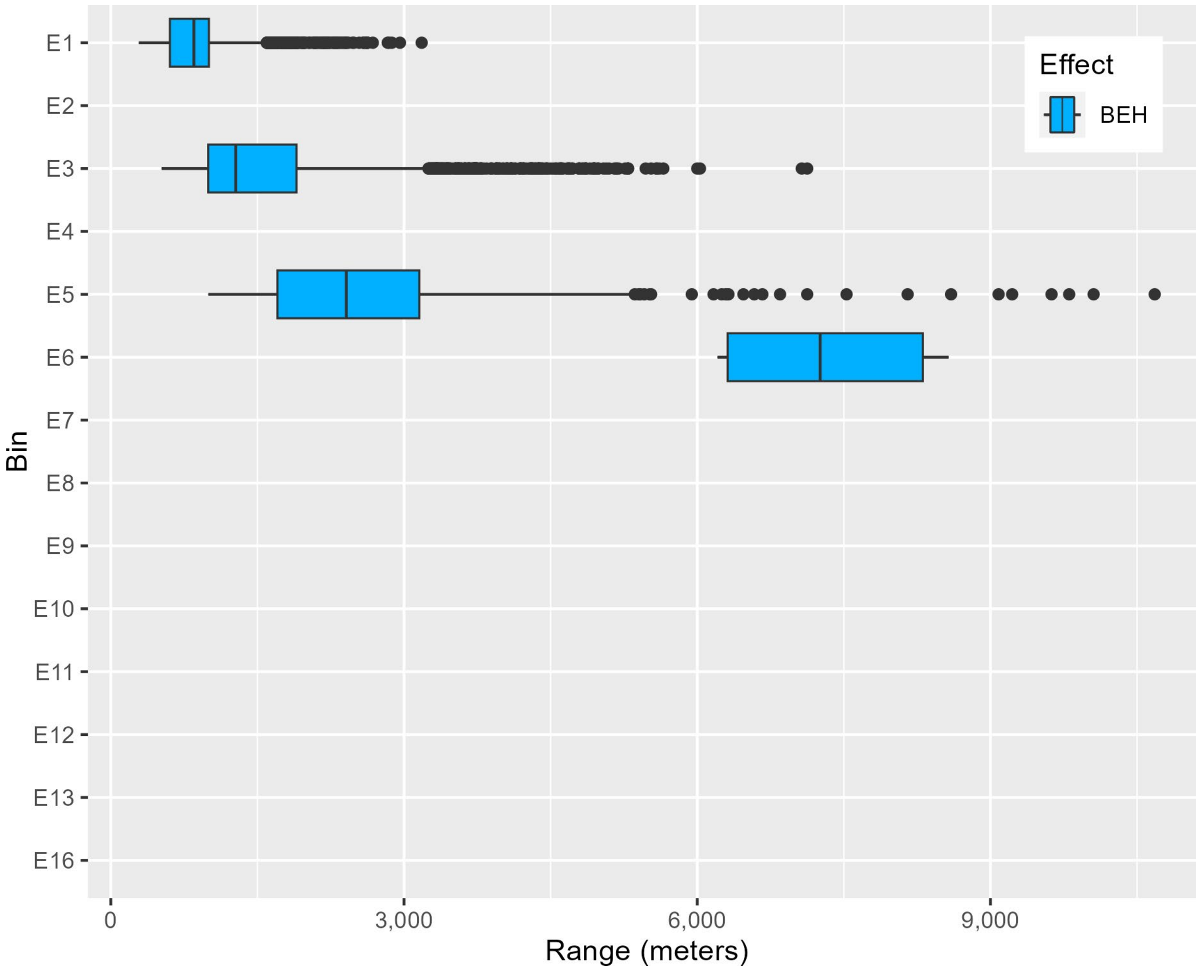

Figure 2.5-17: VLF Cetacean Ranges to Behavioral Response for Explosives

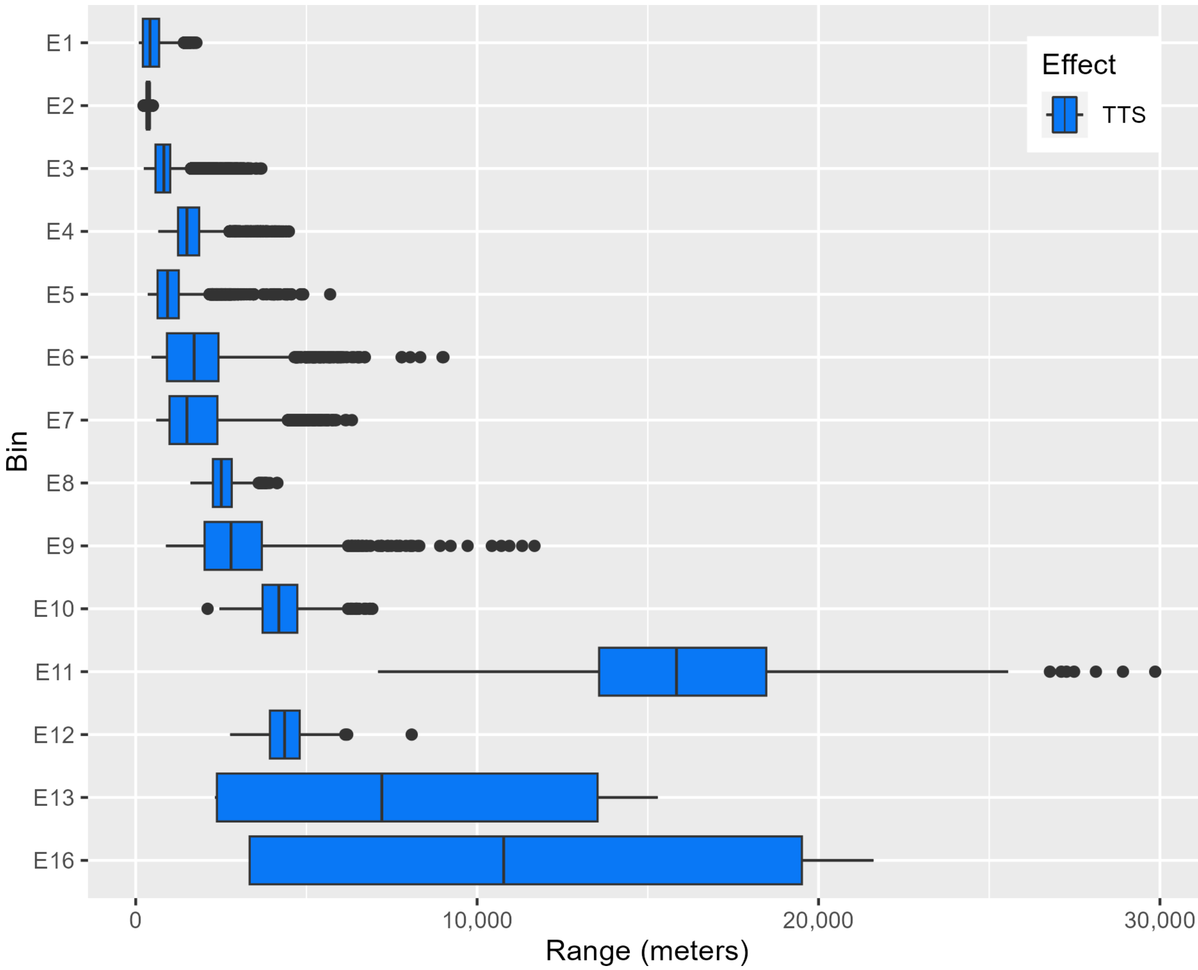

Figure 2.5-18: VLF Cetacean Ranges to Temporary Threshold Shift for Explosives

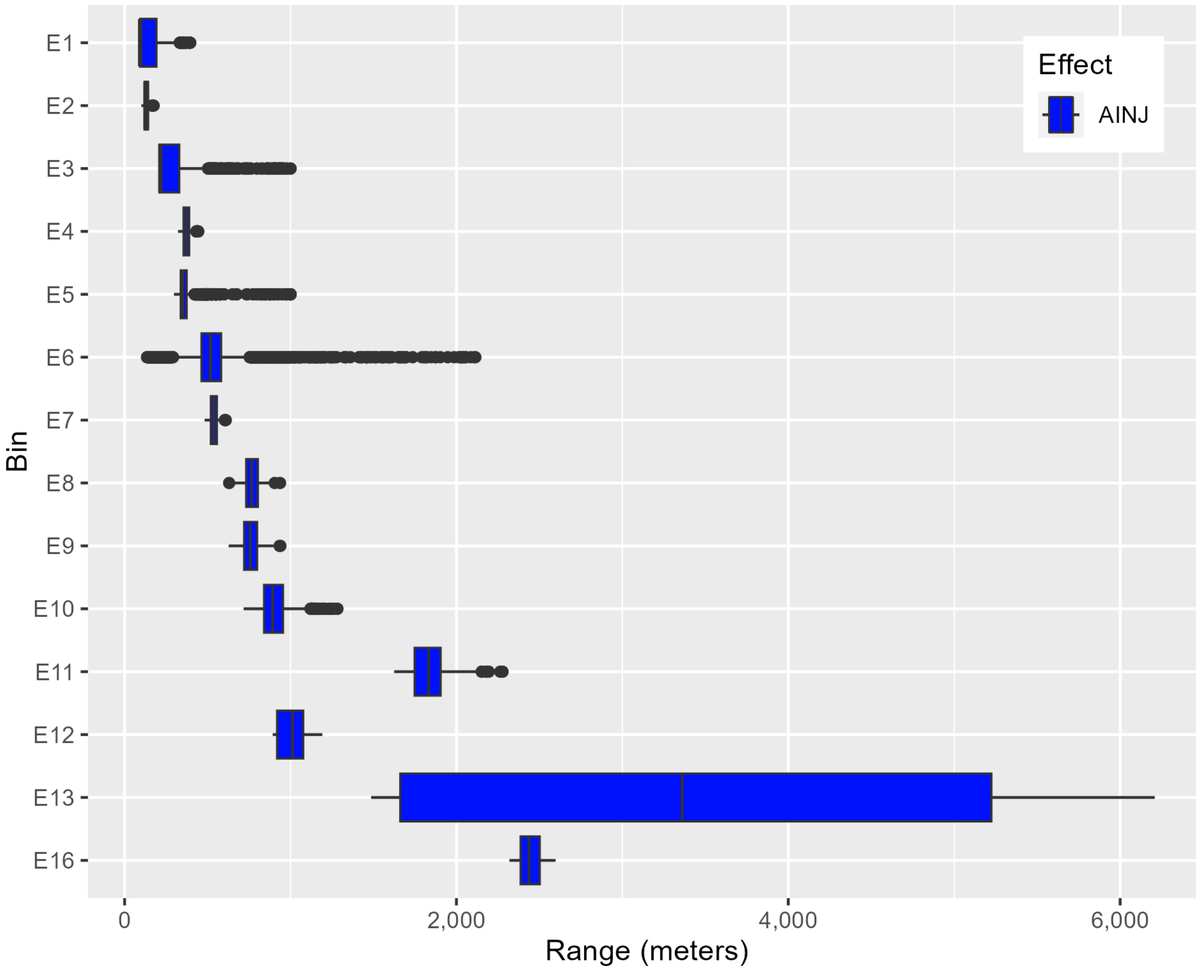

Figure 2.5-19: VLF Cetacean Ranges to Auditory Injury for Explosives

Table 2.5-13: LF Cetacean Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	210 m (75 m)	95 m (4 m)
		5	747 m (231 m)	438 m (165 m)	100 m (23 m)
		25	1,355 m (457 m)	901 m (261 m)	191 m (64 m)
		50	1,457 m (602 m)	846 m (296 m)	240 m (47 m)
	>200 m	1	NA	250 m (61 m)	95 m (4 m)
		5	723 m (140 m)	473 m (88 m)	110 m (8 m)
		25	1,000 m (250 m)	800 m (162 m)	220 m (25 m)
		50	1,000 m (315 m)	950 m (173 m)	310 m (38 m)
E2	≤200 m	1	NA	378 m (45 m)	128 m (13 m)
	>200 m	1	NA	381 m (47 m)	130 m (13 m)
E3	≤200 m	1	NA	535 m (252 m)	202 m (8 m)
		5	1,503 m (562 m)	962 m (327 m)	204 m (87 m)
		25	2,281 m (1,014 m)	1,669 m (605 m)	442 m (159 m)
	>200 m	1	NA	799 m (212 m)	204 m (9 m)
		5	1,000 m (352 m)	850 m (186 m)	240 m (32 m)
		25	1,500 m (957 m)	1,000 m (408 m)	340 m (108 m)
E4	≤200 m	1	NA	1,624 m (658 m)	372 m (37 m)
	>200 m	1	NA	1,000 m (259 m)	361 m (39 m)
E5	≤200 m	1	NA	863 m (762 m)	310 m (30 m)
		5	2,305 m (1,156 m)	1,480 m (604 m)	319 m (83 m)
	>200 m	1	NA	725 m (180 m)	303 m (28 m)
		5	1,917 m (1,004 m)	1,000 m (415 m)	380 m (69 m)
		20	3,958 m (1,082 m)	2,403 m (601 m)	725 m (104 m)
E6	≤200 m	1	NA	1,612 m (1,172 m)	485 m (50 m)
		15	4,916 m (981 m)	3,605 m (763 m)	1,433 m (181 m)
	>200 m	1	NA	1,250 m (879 m)	488 m (49 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E7	≤200 m	1	NA	1,389 m (576 m)	498 m (67 m)
	>200 m	1	NA	1,250 m (1,021 m)	496 m (68 m)
E8	≤200 m	1	NA	2,111 m (309 m)	685 m (62 m)
	>200 m	1	NA	2,062 m (287 m)	681 m (60 m)
E9	≤200 m	1	NA	2,498 m (1,175 m)	722 m (69 m)
	>200 m	1	NA	2,194 m (971 m)	724 m (71 m)
E10	≤200 m	1	NA	3,208 m (554 m)	860 m (91 m)
	>200 m	1	NA	3,191 m (546 m)	859 m (104 m)
E11	≤200 m	1	NA	8,806 m (2,227 m)	1,528 m (129 m)
	>200 m	1	NA	8,910 m (3,010 m)	1,653 m (170 m)
E12	≤200 m	1	NA	3,780 m (412 m)	1,013 m (84 m)
	>200 m	1	NA	3,501 m (503 m)	1,004 m (71 m)
E13	≤200 m	1	NA	4,542 m (1,609 m)	2,757 m (1,128 m)
E16	>200 m	1	NA	5,194 m (1,347 m)	2,667 m (513 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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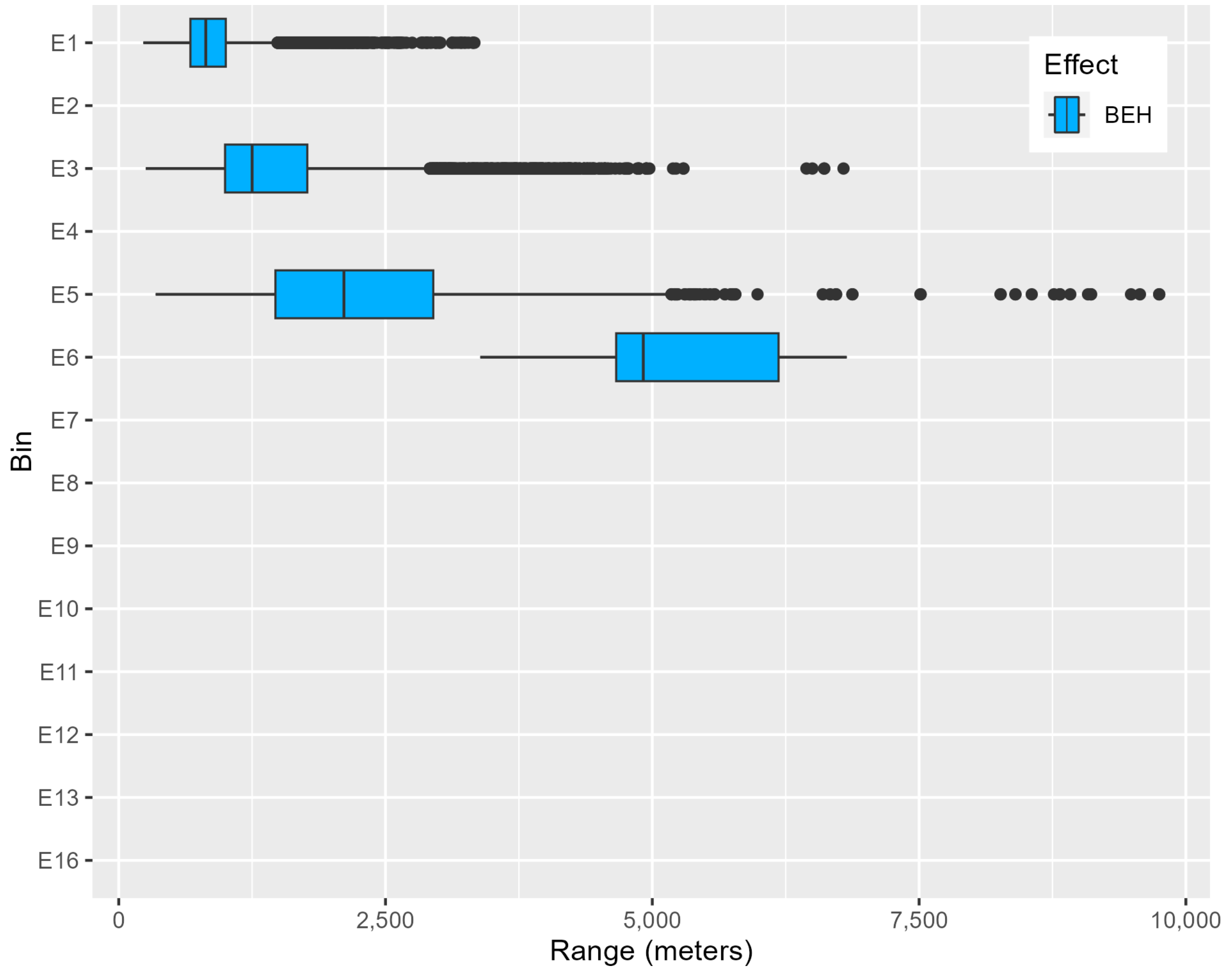

Figure 2.5-20: LF Cetacean Ranges to Behavioral Response for Explosives

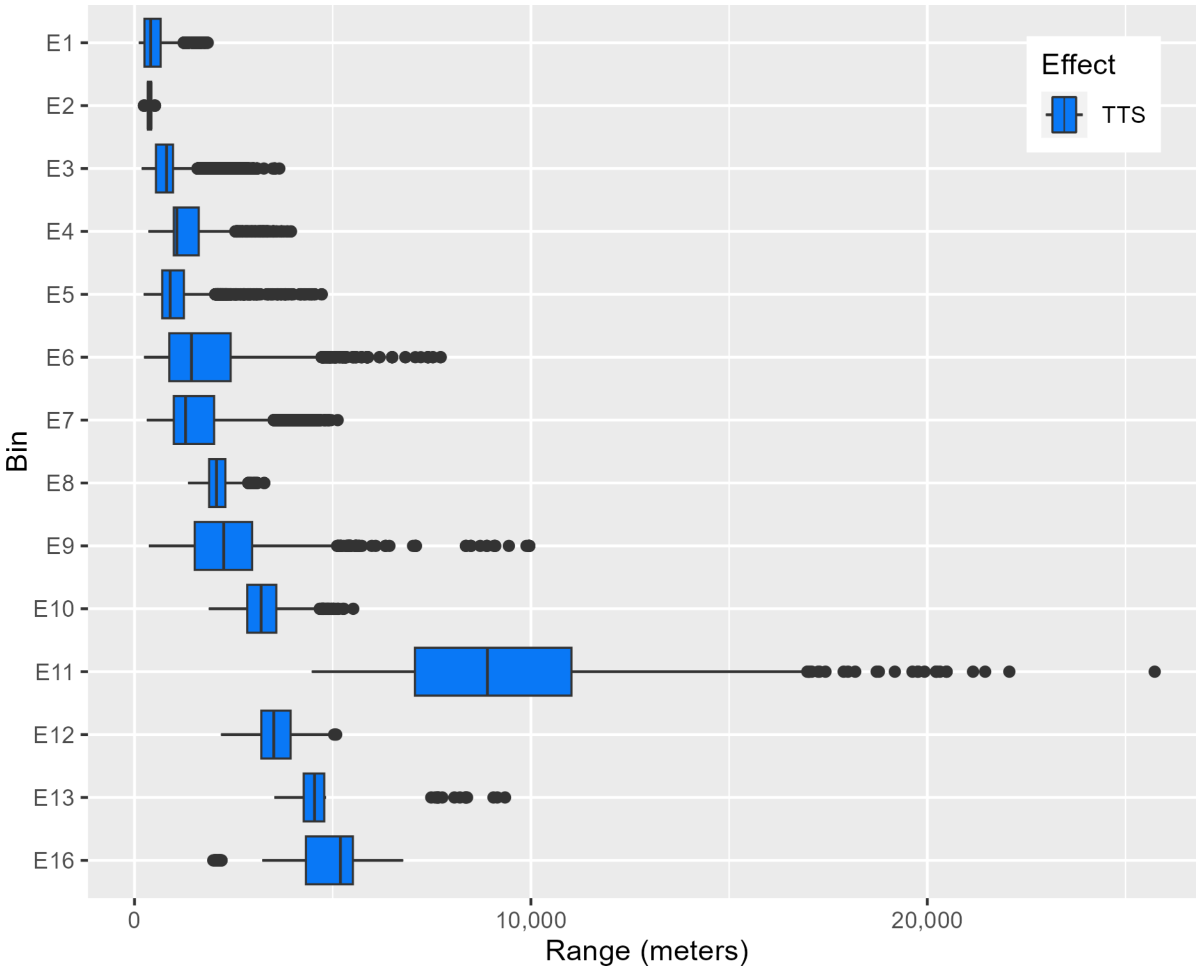

Figure 2.5-21: LF Cetacean Ranges to Temporary Threshold Shift for Explosives

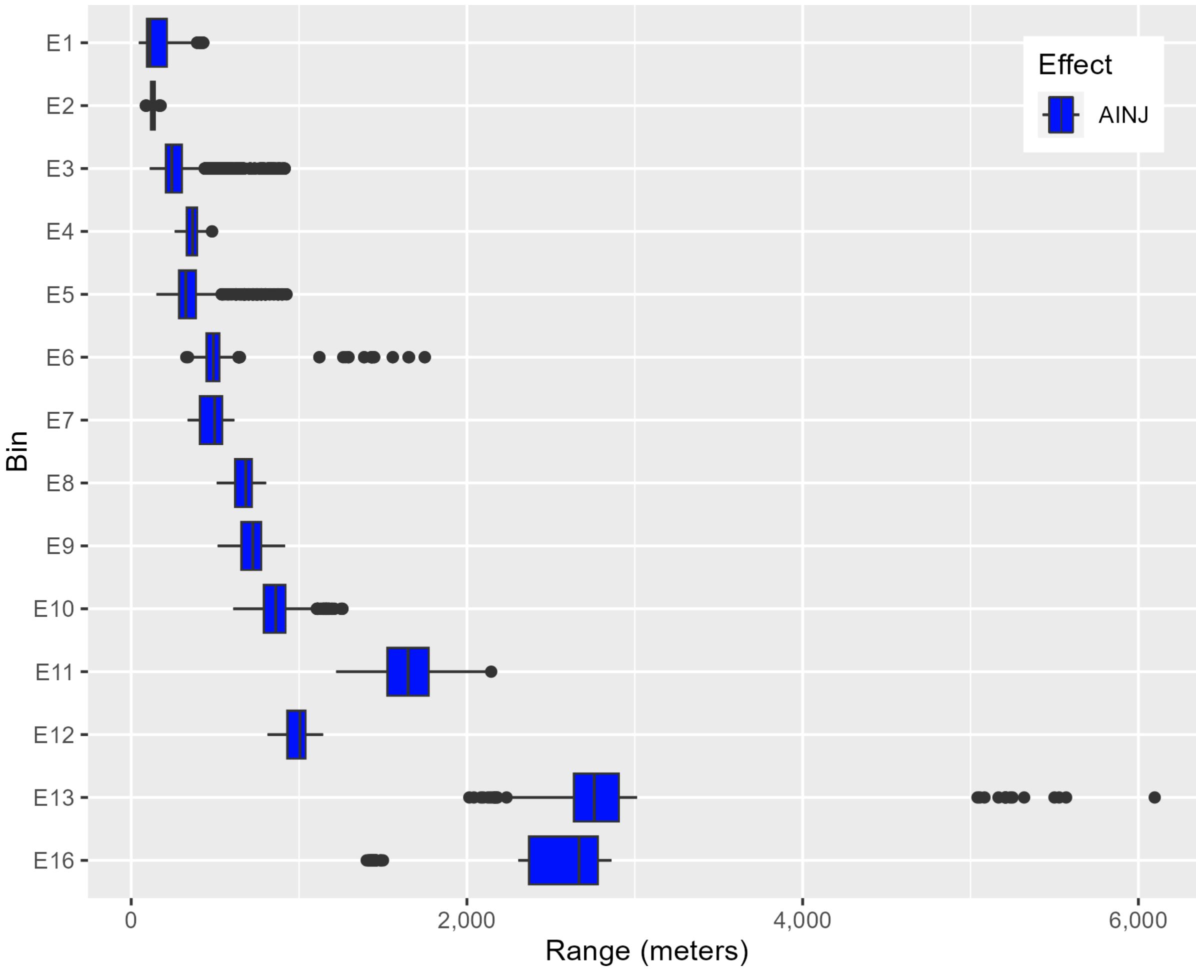

Figure 2.5-22: LF Cetacean Ranges to Auditory Injury for Explosives

Table 2.5-14: HF Cetacean Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	92 m (19 m)	42 m (3 m)
		5	259 m (91 m)	180 m (50 m)	42 m (3 m)
		25	485 m (203 m)	317 m (124 m)	85 m (17 m)
		50	497 m (182 m)	367 m (101 m)	110 m (8 m)
	>200 m	1	NA	90 m (3 m)	42 m (3 m)
		5	280 m (29 m)	180 m (9 m)	42 m (3 m)
		25	490 m (110 m)	310 m (47 m)	85 m (3 m)
		50	760 m (178 m)	500 m (81 m)	110 m (4 m)
E2	≤200 m	1	NA	122 m (9 m)	58 m (5 m)
	>200 m	1	NA	123 m (9 m)	58 m (6 m)
E3	≤200 m	1	NA	180 m (49 m)	93 m (3 m)
		5	493 m (185 m)	321 m (112 m)	93 m (3 m)
		25	860 m (281 m)	592 m (184 m)	144 m (43 m)
	>200 m	1	NA	180 m (15 m)	92 m (4 m)
		5	525 m (107 m)	330 m (47 m)	92 m (4 m)
		25	974 m (256 m)	702 m (177 m)	160 m (6 m)
E4	≤200 m	1	NA	361 m (105 m)	132 m (15 m)
	>200 m	1	NA	279 m (24 m)	129 m (16 m)
E5	≤200 m	1	NA	297 m (139 m)	150 m (13 m)
		5	840 m (231 m)	530 m (169 m)	150 m (13 m)
	>200 m	1	NA	260 m (26 m)	148 m (11 m)
		5	775 m (214 m)	500 m (99 m)	148 m (11 m)
		20	1,171 m (306 m)	840 m (180 m)	220 m (17 m)
E6	≤200 m	1	NA	464 m (221 m)	209 m (22 m)
		15	1,624 m (167 m)	1,223 m (117 m)	427 m (47 m)
	>200 m	1	NA	410 m (85 m)	214 m (20 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E7	≤200 m	1	NA	425 m (138 m)	213 m (37 m)
	>200 m	1	NA	440 m (149 m)	217 m (41 m)
E8	≤200 m	1	NA	609 m (56 m)	333 m (23 m)
	>200 m	1	NA	600 m (54 m)	332 m (23 m)
E9	≤200 m	1	NA	651 m (209 m)	371 m (36 m)
	>200 m	1	NA	696 m (162 m)	373 m (38 m)
E10	≤200 m	1	NA	820 m (125 m)	484 m (61 m)
	>200 m	1	NA	816 m (131 m)	480 m (60 m)
E11	≤200 m	1	NA	1,243 m (78 m)	690 m (33 m)
	>200 m	1	NA	1,308 m (108 m)	729 m (36 m)
E12	≤200 m	1	NA	907 m (185 m)	578 m (90 m)
	>200 m	1	NA	912 m (159 m)	578 m (77 m)
E13	≤200 m	1	NA	5,569 m (4,190 m)	2,701 m (4,433 m)
E16	>200 m	1	NA	3,778 m (8,655 m)	1,882 m (7,911 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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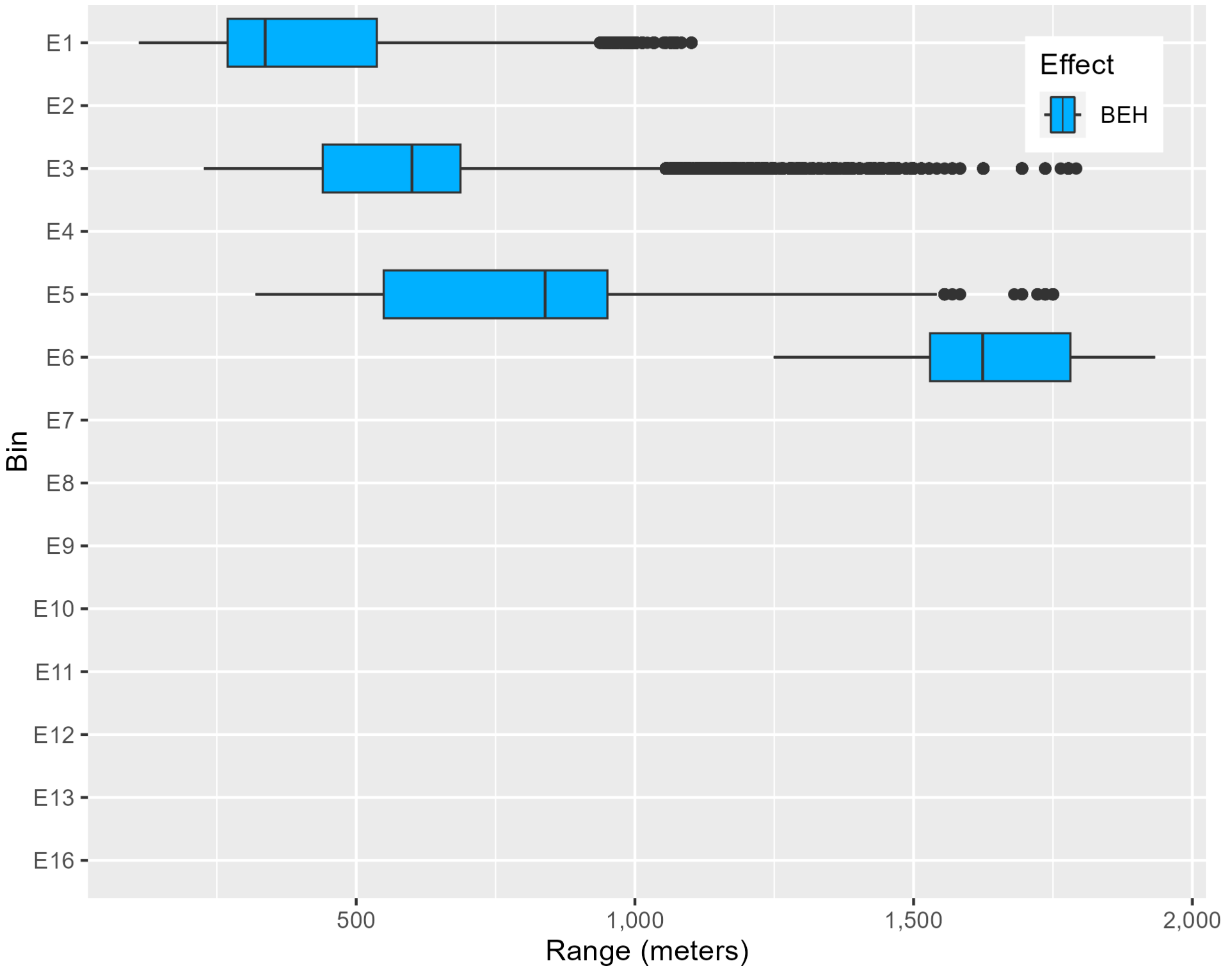

Figure 2.5-23: HF Cetacean Ranges to Behavioral Response for Explosives

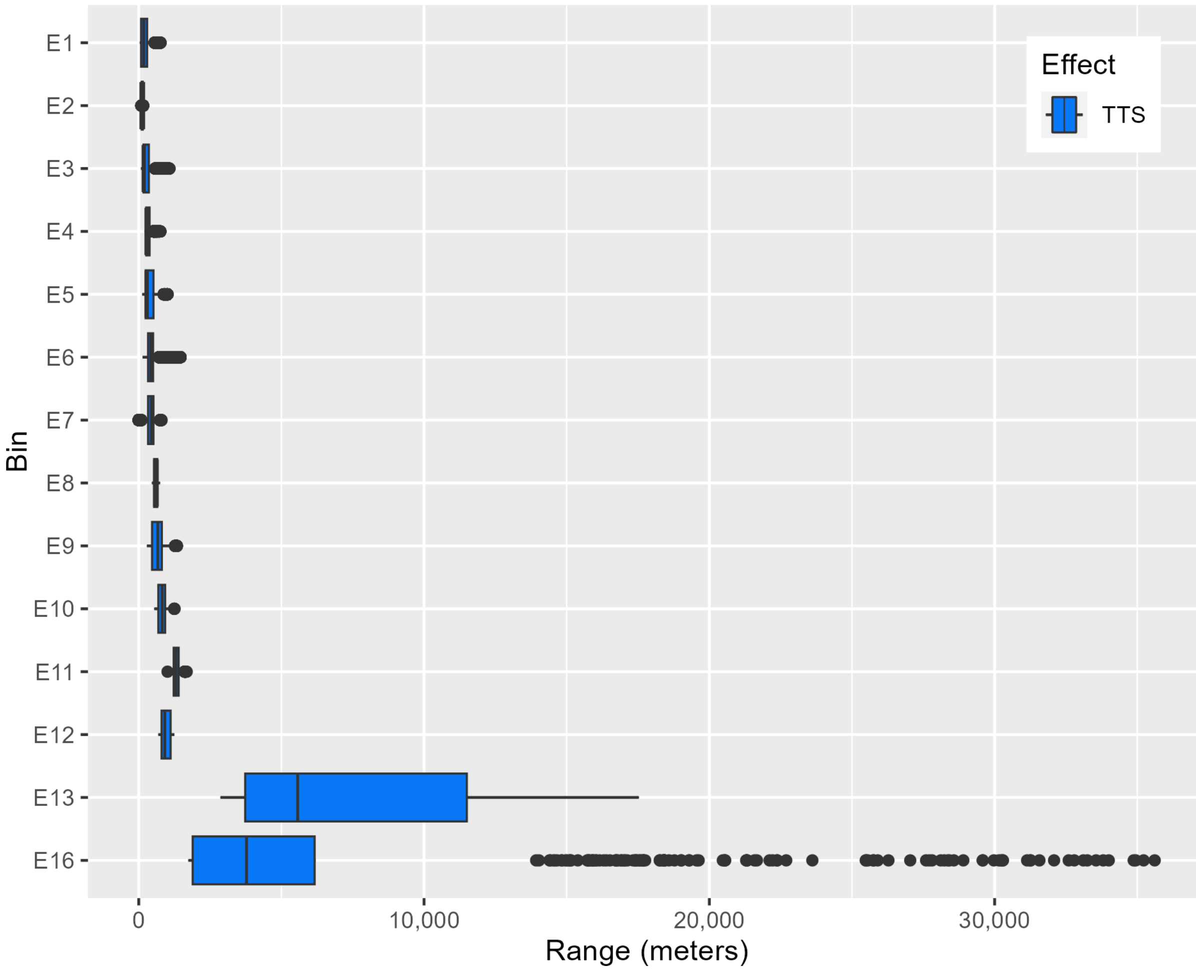

Figure 2.5-24: HF Cetacean Ranges to Temporary Threshold Shift for Explosives

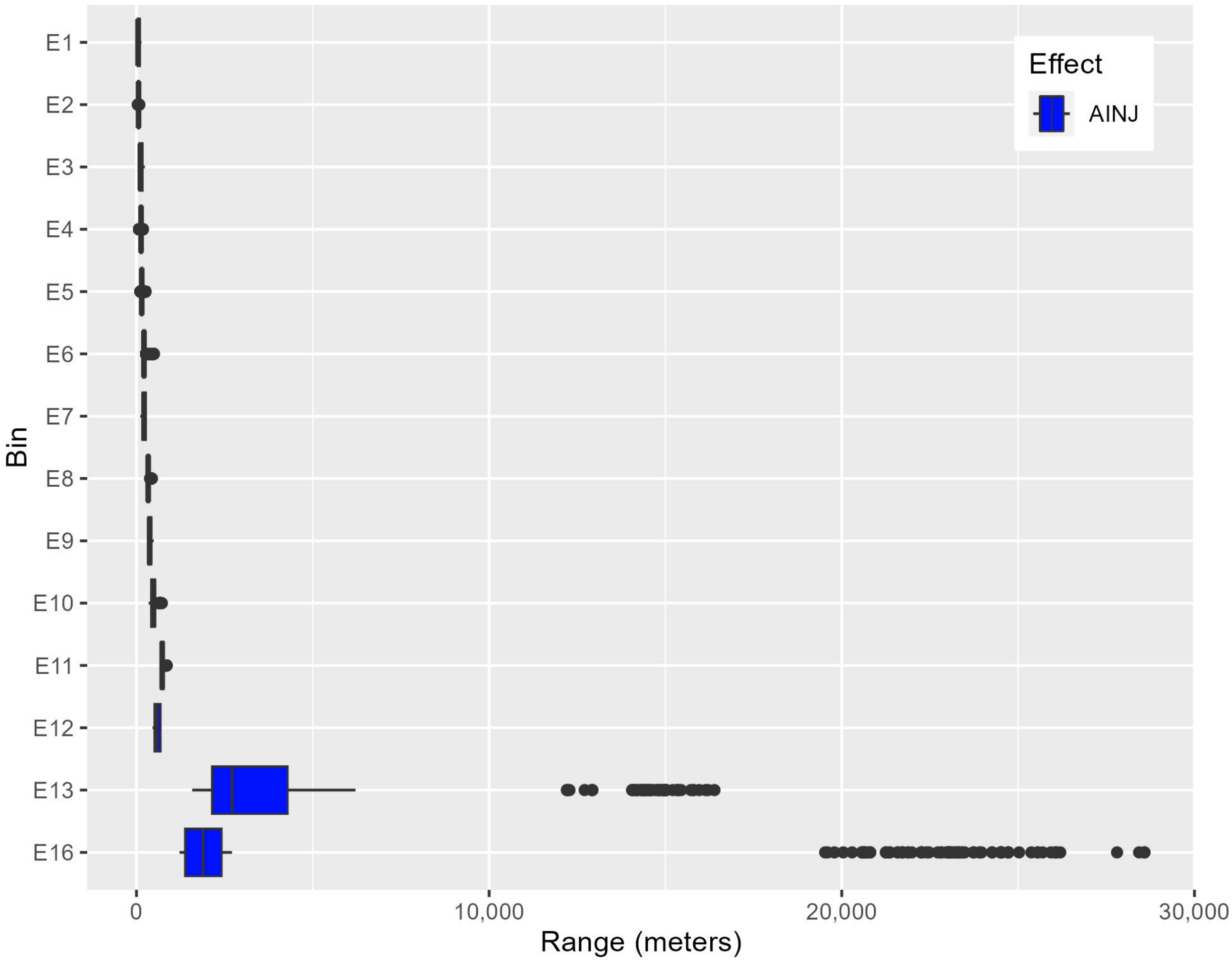

Figure 2.5-25: HF Cetacean Ranges to Auditory Injury for Explosives

Table 2.5-15: VHF Cetacean Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	1,142 m (77 m)	721 m (37 m)
		5	1,861 m (1,411 m)	1,292 m (1,068 m)	721 m (37 m)
		25	2,760 m (1,916 m)	2,222 m (1,575 m)	899 m (585 m)
		50	4,056 m (2,398 m)	2,917 m (2,027 m)	924 m (695 m)
	>200 m	1	NA	1,500 m (414 m)	702 m (34 m)
		5	2,500 m (1,251 m)	2,000 m (734 m)	739 m (105 m)
		25	4,285 m (2,323 m)	2,986 m (1,585 m)	1,250 m (253 m)
		50	3,556 m (2,427 m)	2,750 m (1,577 m)	1,000 m (420 m)
E2	≤200 m	1	NA	1,528 m (133 m)	842 m (54 m)
	>200 m	1	NA	1,548 m (134 m)	842 m (58 m)
E3	≤200 m	1	NA	2,493 m (221 m)	1,542 m (107 m)
		5	2,806 m (1,868 m)	2,493 m (221 m)	1,542 m (107 m)
		25	3,171 m (2,069 m)	2,574 m (1,776 m)	1,542 m (107 m)
	>200 m	1	NA	2,361 m (253 m)	1,417 m (112 m)
		5	3,536 m (2,060 m)	2,750 m (1,364 m)	1,417 m (112 m)
		25	3,000 m (1,737 m)	2,500 m (1,430 m)	1,440 m (536 m)
E4	≤200 m	1	NA	3,389 m (441 m)	2,236 m (219 m)
	>200 m	1	NA	3,361 m (473 m)	2,250 m (229 m)
E5	≤200 m	1	NA	2,403 m (278 m)	1,572 m (148 m)
		5	4,036 m (2,138 m)	3,442 m (1,818 m)	1,750 m (787 m)
	>200 m	1	NA	2,388 m (251 m)	1,551 m (139 m)
		5	5,069 m (3,066 m)	3,917 m (2,154 m)	1,750 m (468 m)
		20	10,750 m (3,002 m)	7,979 m (2,065 m)	2,250 m (577 m)
E6	≤200 m	1	NA	3,974 m (547 m)	2,625 m (323 m)
		15	4,411 m (761 m)	3,974 m (547 m)	2,633 m (362 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
	>200 m	1	NA	3,958 m (547 m)	2,650 m (311 m)
E7	≤200 m	1	NA	4,431 m (442 m)	2,972 m (271 m)
	>200 m	1	NA	4,567 m (530 m)	3,014 m (298 m)
E8	≤200 m	1	NA	8,126 m (2,140 m)	3,590 m (485 m)
	>200 m	1	NA	7,138 m (2,249 m)	3,444 m (401 m)
E9	≤200 m	1	NA	5,611 m (747 m)	3,458 m (428 m)
	>200 m	1	NA	5,458 m (779 m)	3,361 m (369 m)
E10	≤200 m	1	NA	7,133 m (1,055 m)	4,294 m (624 m)
	>200 m	1	NA	6,973 m (1,075 m)	4,184 m (574 m)
E11	≤200 m	1	NA	30,208 m (3,408 m)	18,139 m (3,274 m)
	>200 m	1	NA	27,625 m (4,500 m)	15,778 m (4,177 m)
E12	≤200 m	1	NA	8,361 m (828 m)	4,417 m (452 m)
	>200 m	1	NA	8,861 m (1,666 m)	4,958 m (662 m)
E13	≤200 m	1	NA	11,222 m (3,196 m)	4,931 m (1,169 m)
E16	>200 m	1	NA	6,639 m (6,673 m)	2,257 m (1,560 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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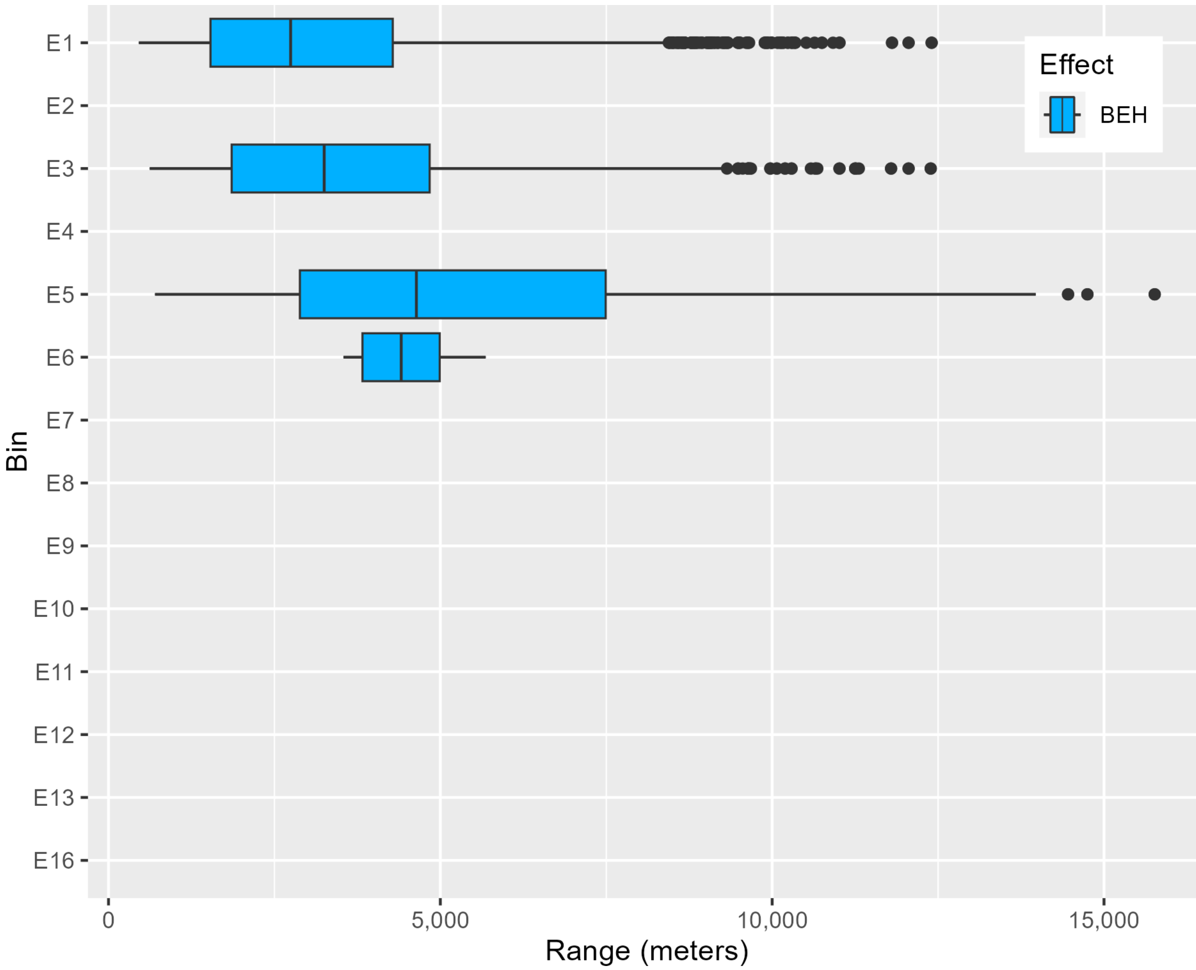

Figure 2.5-26: VHF Cetacean Ranges to Behavioral Response for Explosives

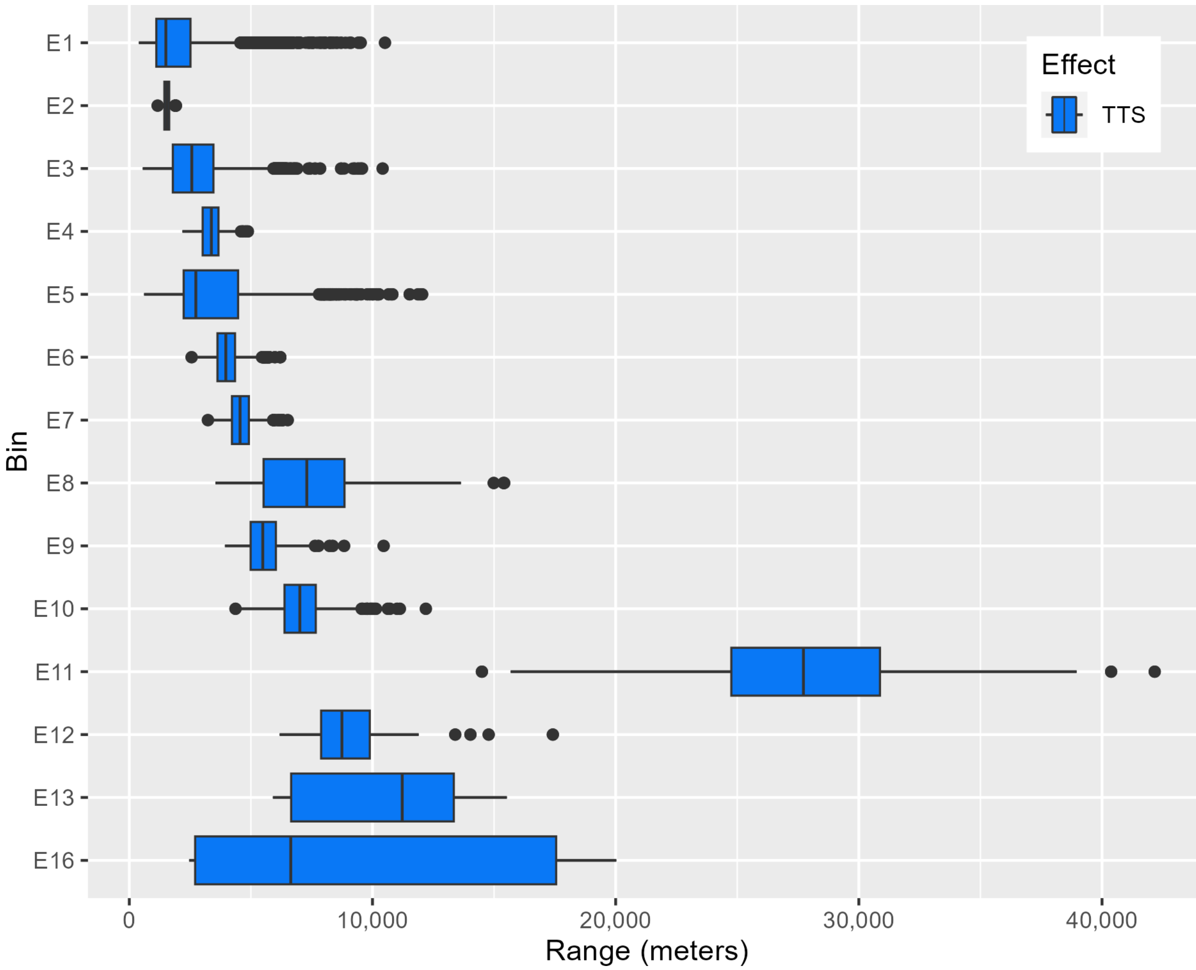

Figure 2.5-27: VHF Cetacean Ranges to Temporary Threshold Shift for Explosives

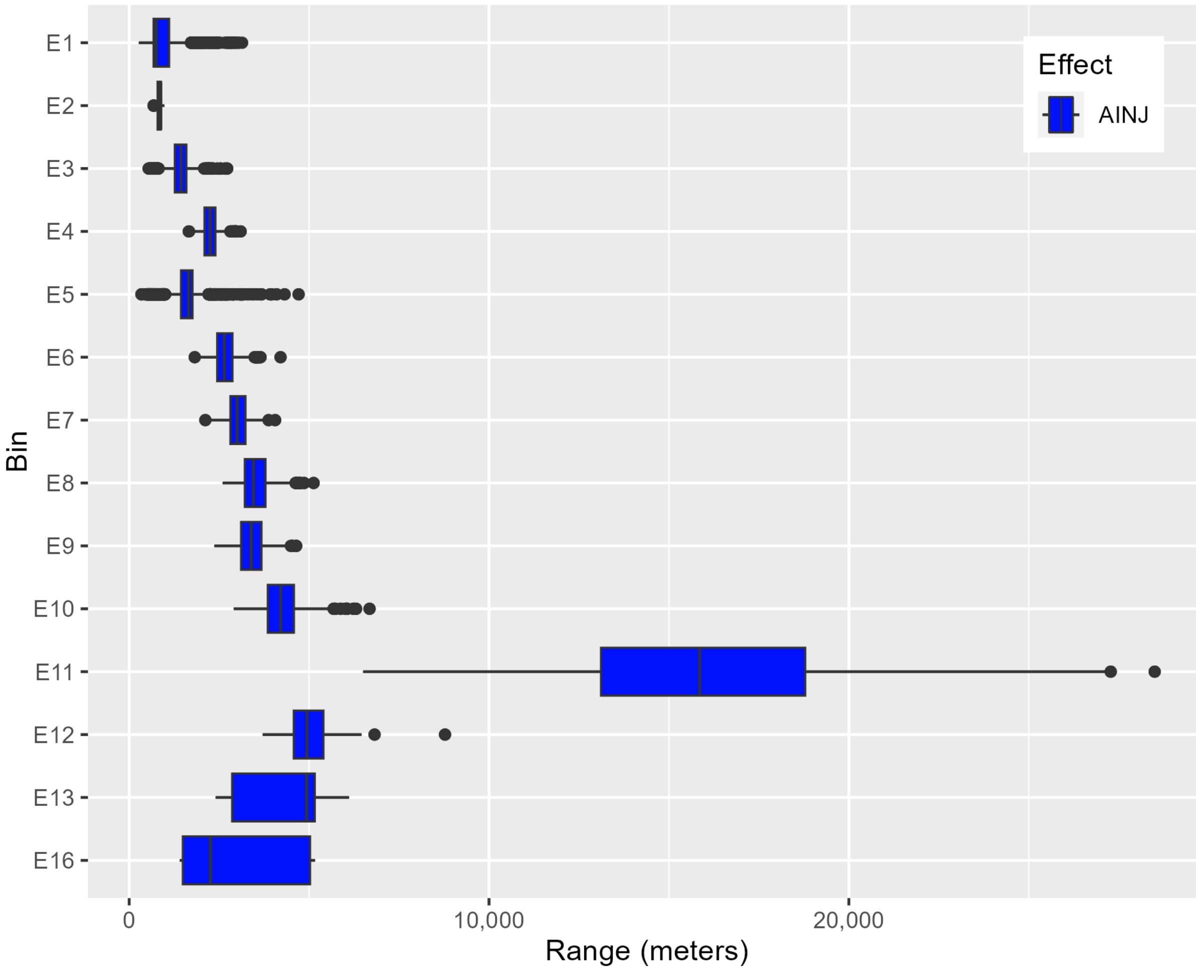

Figure 2.5-28: VHF Cetacean Ranges to Auditory Injury for Explosives

Table 2.5-16: Phocids in Water Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	222 m (67 m)	55 m (10 m)
		5	684 m (210 m)	428 m (147 m)	110 m (28 m)
		25	1,148 m (419 m)	828 m (240 m)	197 m (62 m)
		50	1,264 m (577 m)	785 m (286 m)	259 m (51 m)
	>200 m	1	NA	260 m (41 m)	55 m (4 m)
		5	650 m (179 m)	480 m (86 m)	110 m (4 m)
		25	975 m (359 m)	725 m (207 m)	230 m (19 m)
		50	1,333 m (561 m)	1,000 m (297 m)	305 m (35 m)
E3	≤200 m	1	NA	480 m (216 m)	117 m (33 m)
		5	1,229 m (432 m)	849 m (243 m)	207 m (60 m)
		25	1,967 m (773 m)	1,444 m (465 m)	400 m (115 m)
	>200 m	1	NA	675 m (148 m)	120 m (14 m)
		5	1,065 m (397 m)	875 m (207 m)	240 m (21 m)
		25	2,229 m (889 m)	1,449 m (573 m)	417 m (106 m)
E4	≤200 m	1	NA	1,140 m (446 m)	274 m (36 m)
	>200 m	1	NA	900 m (119 m)	276 m (39 m)
E5	≤200 m	1	NA	767 m (449 m)	191 m (112 m)
		5	1,938 m (830 m)	1,282 m (428 m)	311 m (87 m)
	>200 m	1	NA	725 m (185 m)	181 m (12 m)
		5	1,569 m (852 m)	1,000 m (381 m)	370 m (61 m)
		20	3,542 m (1,172 m)	1,701 m (570 m)	650 m (78 m)
E6	≤200 m	1	NA	1,112 m (710 m)	336 m (177 m)
		15	3,584 m (735 m)	2,786 m (457 m)	1,048 m (152 m)
	>200 m	1	NA	1,000 m (578 m)	300 m (66 m)
E7	≤200 m	1	NA	1,110 m (366 m)	278 m (69 m)
	>200 m	1	NA	1,250 m (551 m)	330 m (123 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E9	≤200 m	1	NA	1,722 m (689 m)	465 m (163 m)
	>200 m	1	NA	1,500 m (655 m)	525 m (105 m)
E13	≤200 m	1	NA	4,139 m (776 m)	2,146 m (522 m)
E16	>200 m	1	NA	2,389 m (840 m)	1,361 m (528 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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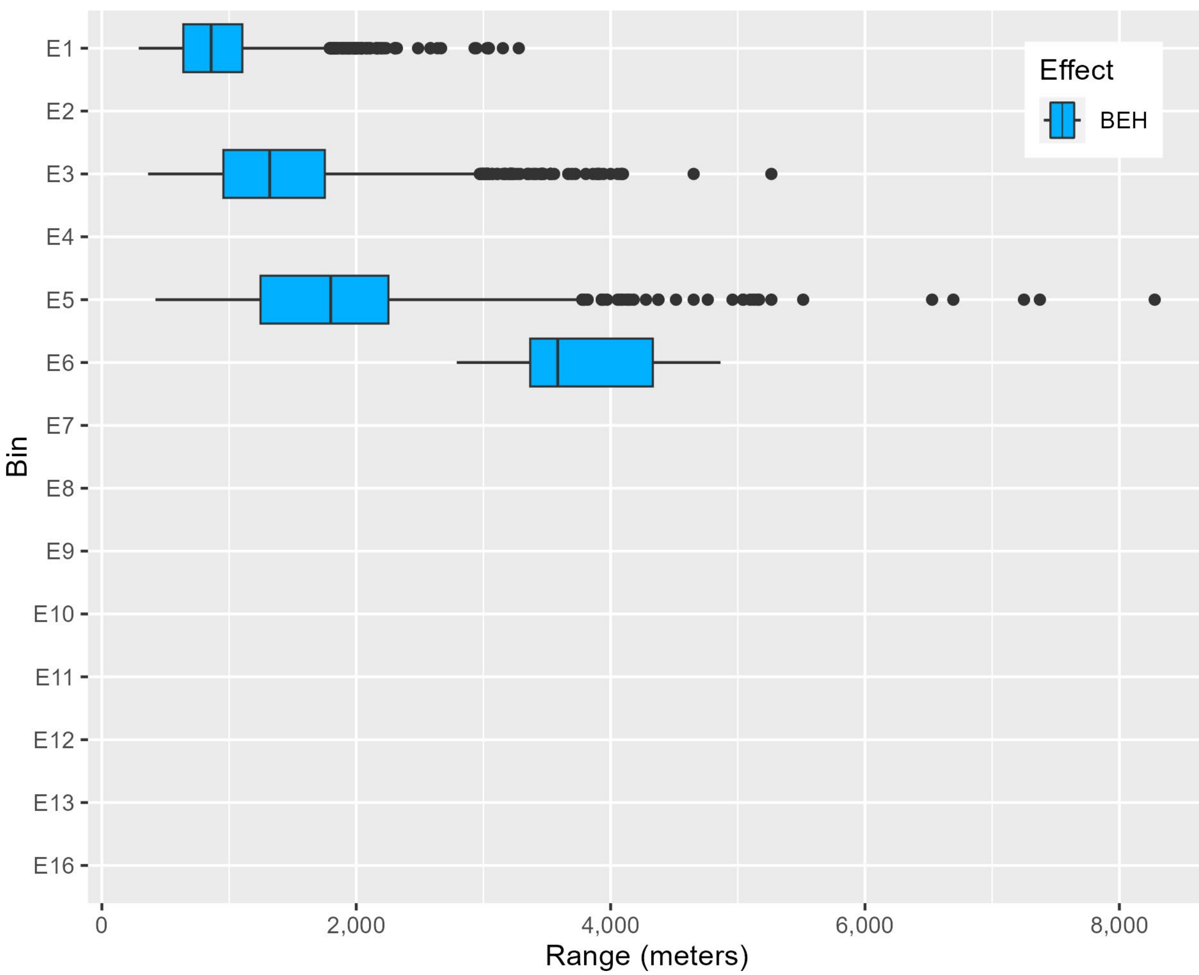

Figure 2.5-29: Phocids in Water Ranges to Behavioral Response for Explosives

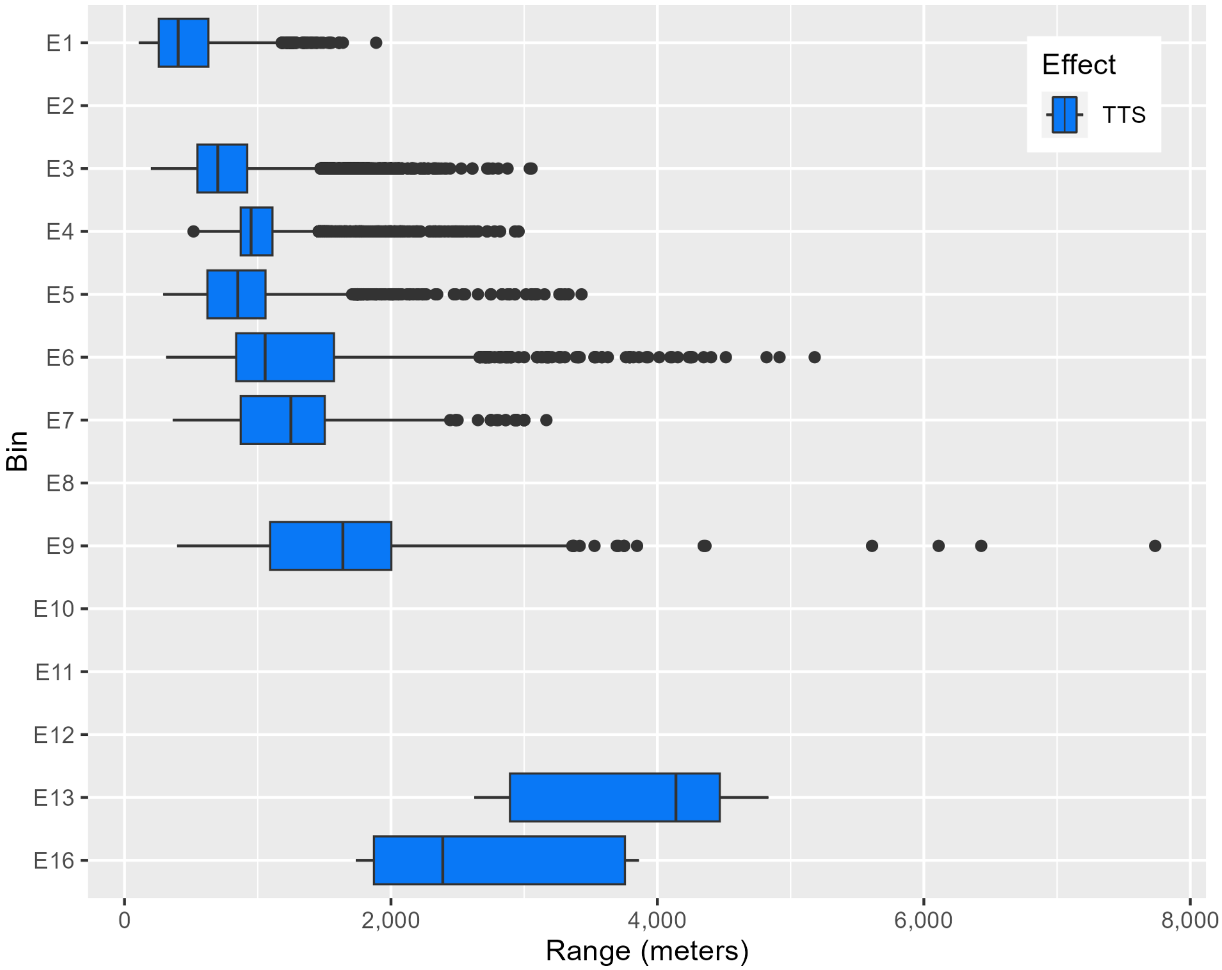

Figure 2.5-30: Phocids in Water Ranges to Temporary Threshold Shift for Explosives

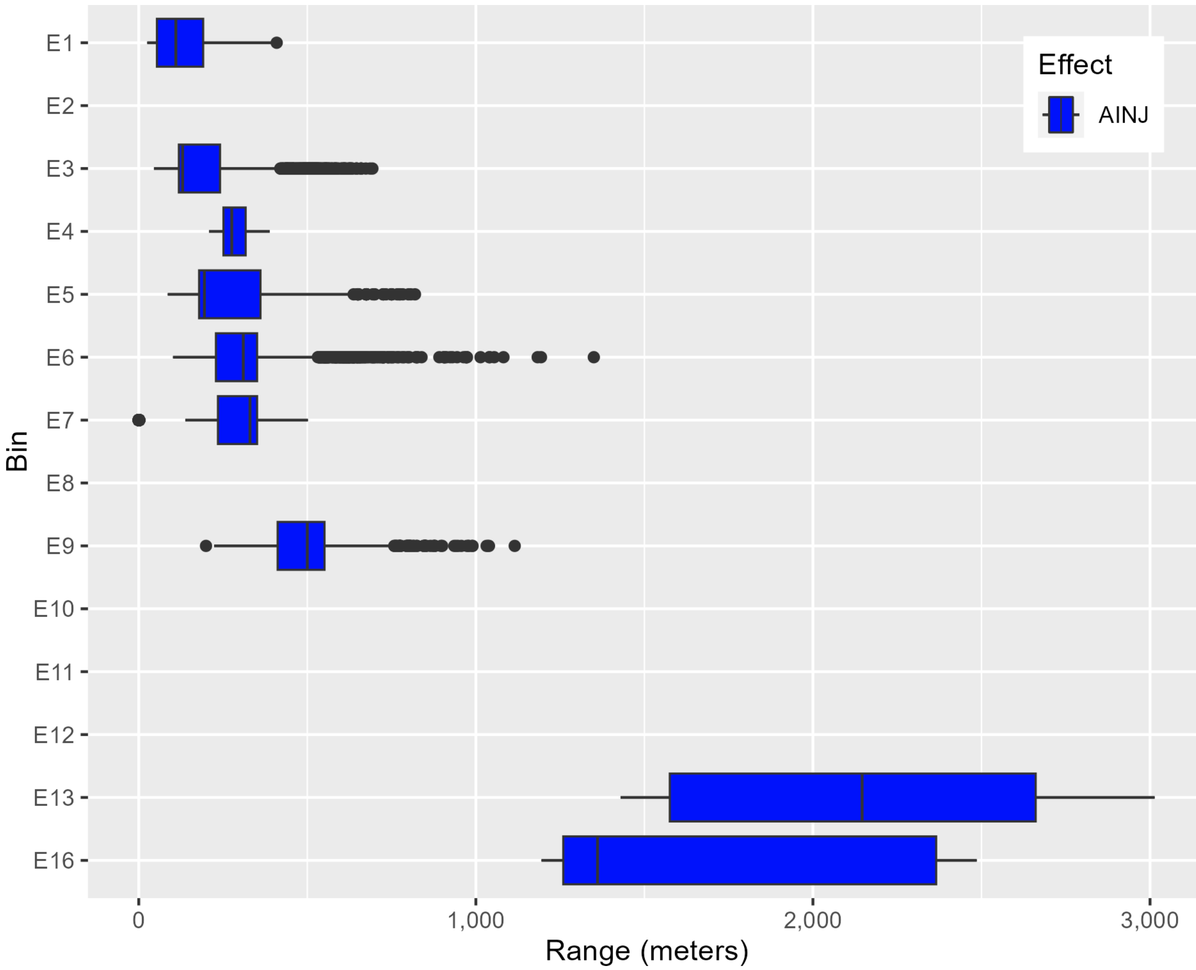

Figure 2.5-31: Phocids in Water Ranges to Auditory Injury for Explosives

Table 2.5-17: Otariids in Water Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	150 m (48 m)	40 m (5 m)
		5	430 m (172 m)	288 m (104 m)	83 m (18 m)
		25	800 m (306 m)	561 m (200 m)	138 m (46 m)
		50	835 m (454 m)	550 m (229 m)	210 m (37 m)
	>200 m	1	NA	190 m (27 m)	40 m (2 m)
		5	450 m (81 m)	324 m (54 m)	85 m (4 m)
		25	589 m (144 m)	480 m (97 m)	170 m (19 m)
		50	742 m (128 m)	575 m (93 m)	230 m (30 m)
E3	≤200 m	1	NA	313 m (129 m)	80 m (22 m)
		5	771 m (286 m)	543 m (186 m)	140 m (42 m)
		25	1,324 m (575 m)	928 m (357 m)	260 m (93 m)
	>200 m	1	NA	400 m (116 m)	80 m (18 m)
		5	650 m (135 m)	500 m (91 m)	170 m (19 m)
		25	850 m (313 m)	656 m (168 m)	300 m (54 m)
E4	≤200 m	1	NA	778 m (194 m)	125 m (36 m)
	>200 m	1	NA	550 m (124 m)	116 m (15 m)
E5	≤200 m	1	NA	537 m (255 m)	140 m (36 m)
		5	1,315 m (469 m)	913 m (280 m)	221 m (62 m)
	>200 m	1	NA	430 m (79 m)	130 m (9 m)
		5	740 m (210 m)	575 m (136 m)	250 m (40 m)
E6	≤200 m	1	NA	821 m (382 m)	200 m (86 m)
		15	2,221 m (258 m)	1,767 m (186 m)	791 m (65 m)
	>200 m	1	NA	575 m (275 m)	180 m (36 m)
E7	≤200 m	1	NA	727 m (244 m)	200 m (47 m)
	>200 m	1	NA	625 m (209 m)	180 m (98 m)
E9	≤200 m	1	NA	940 m (361 m)	279 m (89 m)
	>200 m	1	NA	715 m (158 m)	319 m (51 m)
E13	≤200 m	1	NA	4,514 m (1,620 m)	2,701 m (1,249 m)
E16	>200 m	1	NA	3,708 m (7,259 m)	2,181 m (822 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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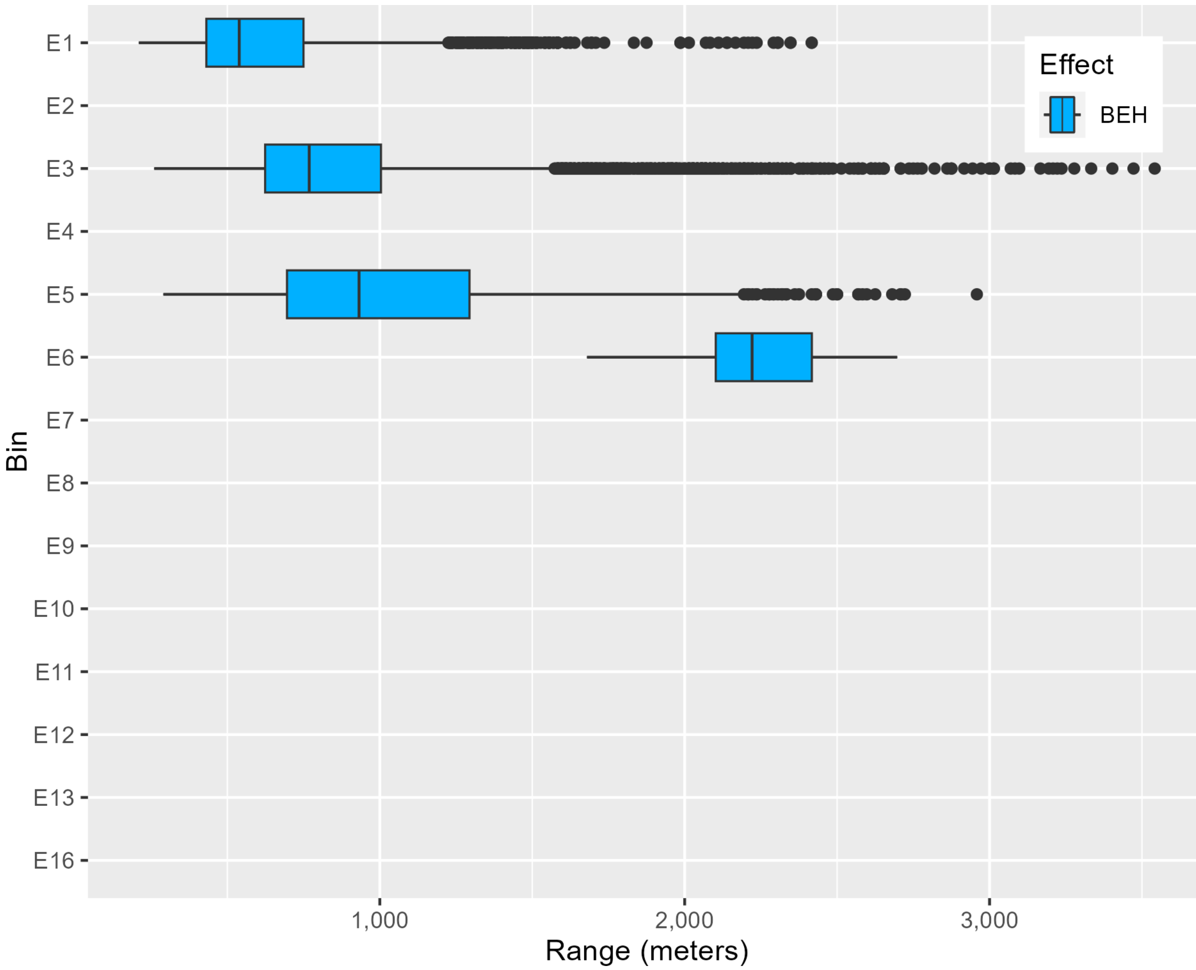

Figure 2.5-32: Otariids in Water Ranges to Behavioral Response for Explosives

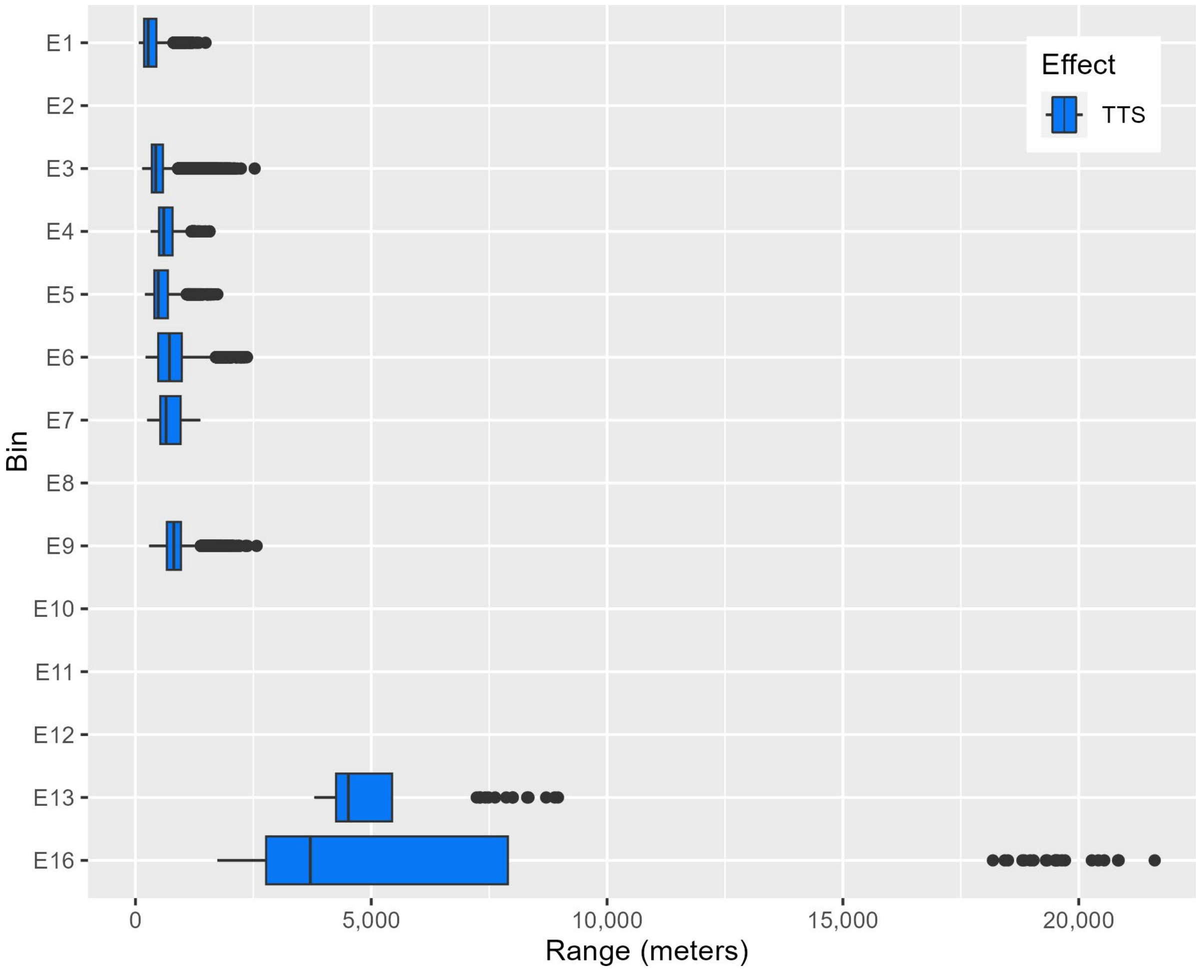

Figure 2.5-33: Otariids in Water Ranges to Temporary Threshold Shift for Explosives

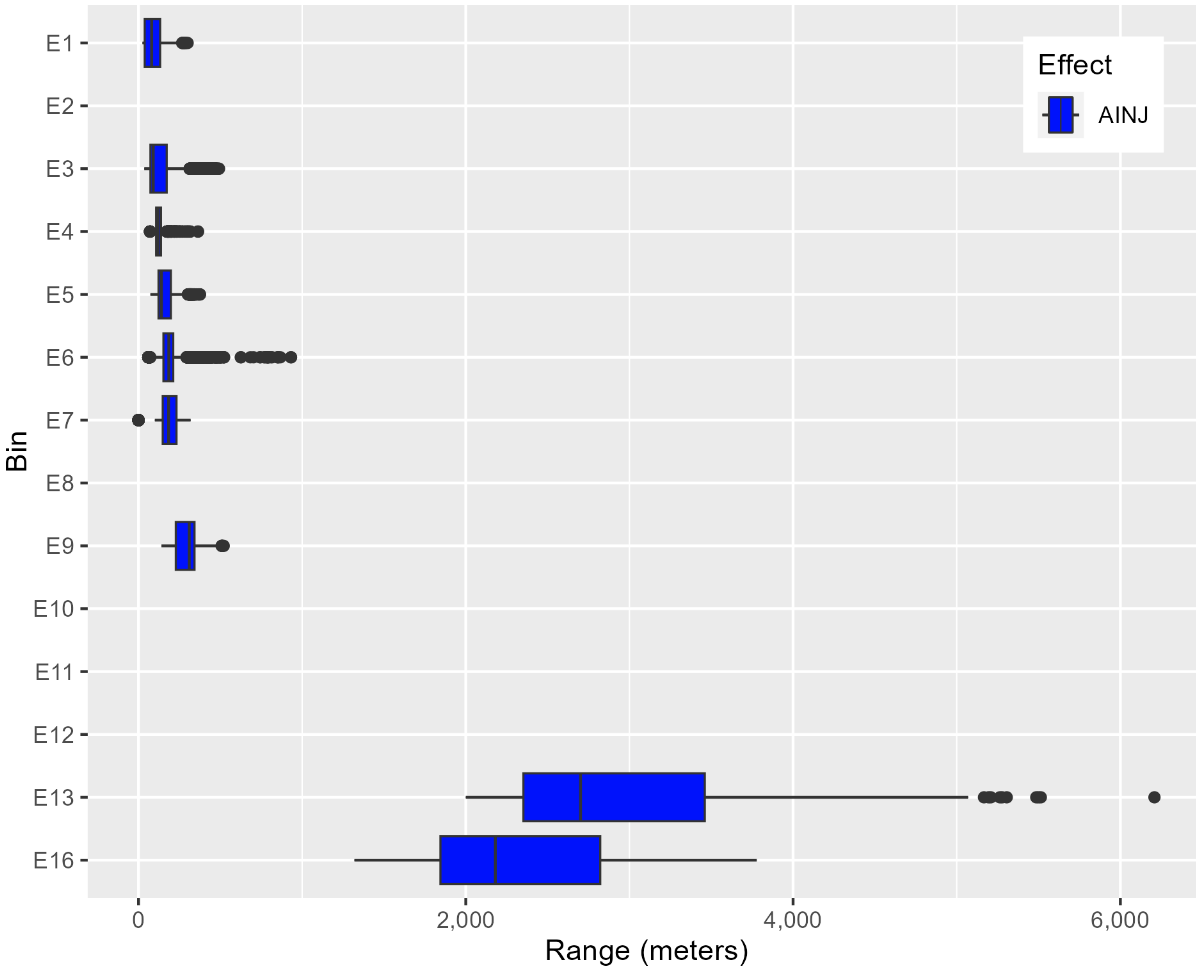

Figure 2.5-34: Otariids in Water Ranges to Auditory Injury for Explosives

Table 2.5-18: Explosive Ranges to Injury and Mortality for All Marine Mammal Hearing Groups as a Function of Animal Mass

Bin	Effect	10 kg	250 kg	1,000 kg	5,000 kg	25,000 kg	72,000 kg
E1	INJ	22 m (0 m)	21 m (1 m)	22 m (1 m)	21 m (2 m)	22 m (1 m)	21 m (1 m)
	MORT	3 m (0 m)	1 m (1 m)	0 m (0 m)	0 m (0 m)	0 m (0 m)	0 m (0 m)
E2	INJ	27 m (2 m)	27 m (2 m)	26 m (2 m)	25 m (2 m)	26 m (2 m)	26 m (1 m)
	MORT	6 m (1 m)	2 m (1 m)	1 m (0 m)	0 m (0 m)	0 m (0 m)	0 m (0 m)
E3	INJ	36 m (5 m)	36 m (6 m)	39 m (5 m)	43 m (3 m)	40 m (3 m)	45 m (1 m)
	MORT	7 m (1 m)	3 m (1 m)	1 m (1 m)	0 m (0 m)	0 m (0 m)	0 m (0 m)
E4	INJ	54 m (5 m)	56 m (6 m)	59 m (6 m)	60 m (6 m)	60 m (7 m)	59 m (5 m)
	MORT	19 m (4 m)	8 m (4 m)	3 m (1 m)	1 m (0 m)	1 m (0 m)	0 m (0 m)
E5	INJ	76 m (2 m)	76 m (4 m)	76 m (3 m)	76 m (3 m)	76 m (3 m)	76 m (2 m)
	MORT	16 m (2 m)	7 m (3 m)	3 m (1 m)	2 m (1 m)	0 m (0 m)	0 m (0 m)
E6	INJ	103 m (8 m)	101 m (8 m)	102 m (9 m)	103 m (8 m)	102 m (9 m)	102 m (8 m)
	MORT	40 m (8 m)	18 m (6 m)	9 m (1 m)	6 m (1 m)	3 m (1 m)	2 m (0 m)
E7	INJ	106 m (17 m)	106 m (17 m)	107 m (18 m)	111 m (15 m)	102 m (19 m)	107 m (12 m)
	MORT	19 m (2 m)	10 m (3 m)	5 m (1 m)	3 m (1 m)	2 m (1 m)	1 m (0 m)
E8	INJ	222 m (14 m)	160 m (7 m)	158 m (8 m)	164 m (4 m)	152 m (7 m)	165 m (3 m)
	MORT	64 m (10 m)	28 m (12 m)	14 m (3 m)	10 m (2 m)	5 m (1 m)	3 m (1 m)

Bin	Effect	10 kg	250 kg	1,000 kg	5,000 kg	25,000 kg	72,000 kg
E9	INJ	354 m (40 m)	192 m (11 m)	188 m (14 m)	206 m (12 m)	184 m (11 m)	211 m (8 m)
	MORT	162 m (20 m)	21 m (28 m)	11 m (1 m)	8 m (1 m)	4 m (1 m)	2 m (1 m)
E10	INJ	510 m (80 m)	242 m (21 m)	243 m (22 m)	258 m (25 m)	241 m (20 m)	268 m (20 m)
	MORT	262 m (36 m)	58 m (65 m)	14 m (4 m)	10 m (2 m)	5 m (1 m)	4 m (0 m)
E11	INJ	653 m (32 m)	366 m (25 m)	370 m (22 m)	360 m (21 m)	364 m (21 m)	370 m (19 m)
	MORT	346 m (14 m)	162 m (48 m)	87 m (9 m)	57 m (7 m)	26 m (3 m)	22 m (3 m)
E12	INJ	660 m (73 m)	338 m (153 m)	327 m (14 m)	344 m (34 m)	327 m (7 m)	353 m (2 m)
	MORT	365 m (38 m)	145 m (92 m)	18 m (1 m)	13 m (1 m)	7 m (1 m)	5 m (0 m)
E13	INJ	4,167 m (1,504 m)	2,135 m (1,522 m)	1,906 m (1,156 m)	2,073 m (1,404 m)	1,199 m (1,046 m)	953 m (182 m)
	MORT	1,831 m (783 m)	717 m (759 m)	573 m (572 m)	677 m (658 m)	335 m (410 m)	260 m (202 m)
E16	INJ	1,597 m (484 m)	1,000 m (628 m)	1,053 m (205 m)	1,069 m (341 m)	1,081 m (257 m)	975 m (4 m)
	MORT	1,024 m (225 m)	678 m (284 m)	665 m (214 m)	753 m (263 m)	529 m (277 m)	415 m (233 m)

Median ranges with standard deviation ranges in parentheses, INJ = the greater of respective ranges for 1% chance of gastro-intestinal tract injury and 1% chance of injury, MORT = mortality
E1 (0.1 - 0.25 lbs), E2 (>0.25 - 0.5 lbs), E3 (>0.5 - 2.5 lbs), E4 (>2.5 - 5 lbs), E5 (>5 - 10 lbs), E6 (>10 - 20 lbs), E7 (>20 - 60 lbs), E8 (>60 - 100 lbs), E9 (>100 - 250 lbs), E10 (>250 - 500 lbs), E11 (>500 - 675 lbs), E12 (>675 - 1,000 lbs), E13 (>1,000 - 1,740), E16 (10,000 lbs)
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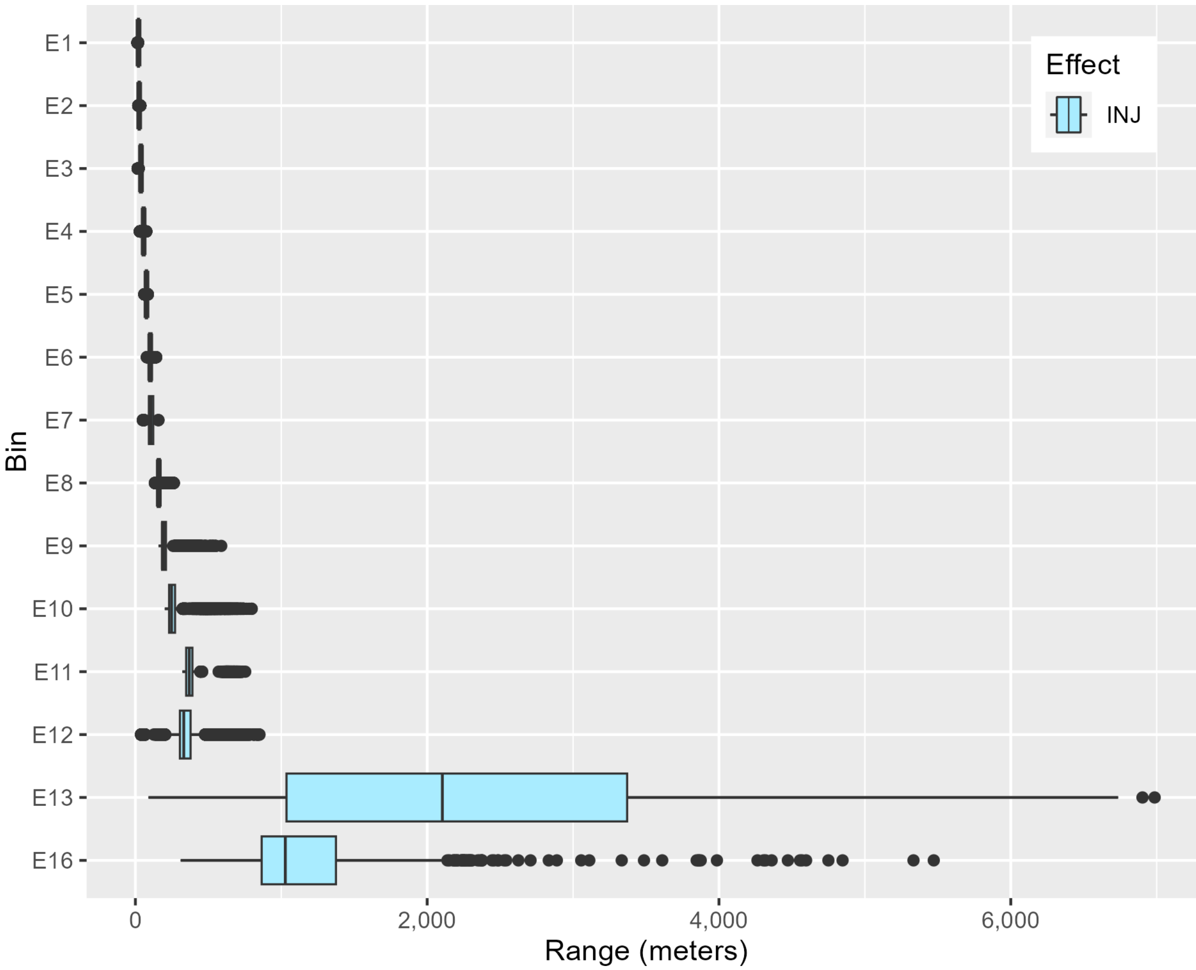


Figure 2.5-35: Explosive Ranges to Injury for All Marine Mammal Hearing Groups

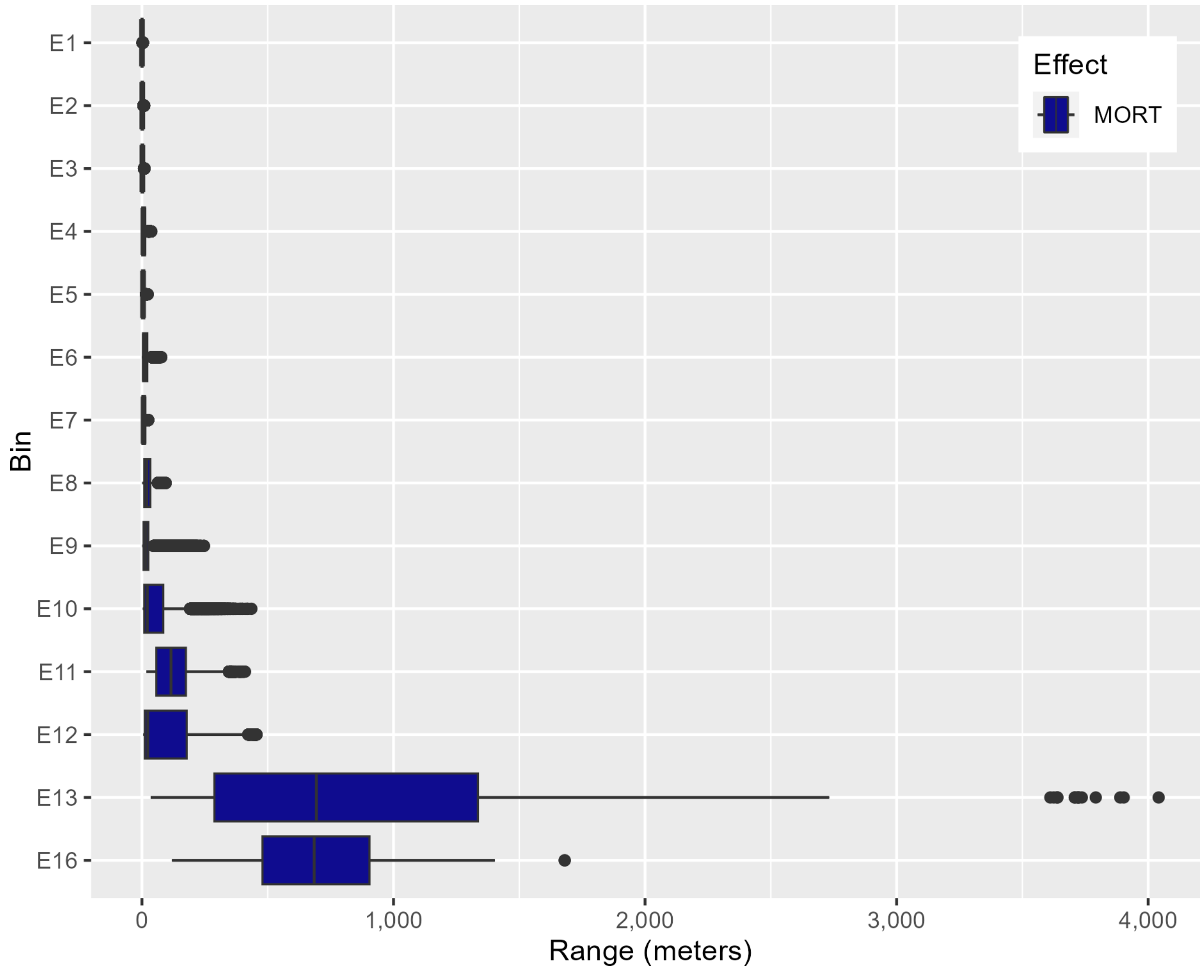


Figure 2.5-36: Explosive Ranges to Mortality for All Marine Mammal Hearing Groups

3 IMPACTS ON REPTILES FROM ACOUSTIC AND EXPLOSIVE STRESSORS

This analysis is presented as follows:

- The impacts that would be expected due to each type of acoustic stressor and explosives used in the Proposed Action are described in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives)
- The approach to modeling and quantifying impacts is summarized in Section 3.2 (Quantifying Impacts on Reptiles from Acoustic and Explosive Stressors).
- Impacts on ESA-listed species in the Study Area, including predicted instances of harm or harassment, are presented in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1 IMPACTS DUE TO EACH ACOUSTIC SUBSTRESSOR AND EXPLOSIVES

Assessing whether a sound may disturb or injure a reptile involves understanding the characteristics of the acoustic sources, the reptiles that may be present in the vicinity of the sources, and the effects that sound may have on the physiology and behavior of reptiles. Many other factors besides just the received level of sound may affect an animal's reaction, such as the duration of the sound-producing activity, the animal's physical condition, prior experience with the sound, activity at the time of exposure (e.g., feeding, traveling, resting), the context of the exposure (e.g., in a semi-enclosed bay vs. open ocean), and proximity of the animal to the source of the sound.

The *Reptile Acoustic Background* section summarizes what is currently known about acoustic effects to reptiles. For all acoustic substressors and explosives, the reader is referred to that section for background information on the types of effects that are discussed in the following analysis. In this analysis, impacts are categorized as mortality, non-auditory injury, temporary hearing loss (temporary threshold shift [TTS]), auditory injury (AINJ, including permanent threshold shift [PTS] and auditory neural injury), other physiological response (including stress), masking (occurs when a noise interferes with the detection, discrimination, or recognition of other sounds), and behavioral responses.

3.1.1 IMPACTS FROM SONARS AND OTHER TRANSDUCERS

Sonars and other transducers (collectively referred to as sonars in this analysis) emit sound waves into the water to detect objects, safely navigate, and communicate. Sonars are considered non-impulsive and vary in source level, frequency, duration (the total time that a source emits sound including any silent periods between pings), duty cycle (the portion of time a sonar emits sound when active, from infrequent to continuous), beam characteristics (narrow to wide, directional to omnidirectional, downward or forward facing), and movement (stationary or on a moving platform). Additional characteristics and occurrence of sonars used under the Proposed Action are described in the *Acoustic Stressors* and *Activity Descriptions* sections.

Reptiles are likely only susceptible to hearing loss when exposed to high levels of sound within their limited hearing range (most sensitive from 100–400 Hz and limited over 1 kHz). Only sources within the hearing range of reptiles (<2 kHz) are considered. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles.

Potential impacts from exposures to sonar are discussed in the *Reptile Acoustic Background* section and include TTS, AINJ, masking, behavioral reactions, and physiological response.

Military readiness activities that involve the use of sonars could occur throughout the Study Area, although use would generally occur in Navy range complexes and testing ranges, or around inshore locations, and specified ports and piers identified in the *Proposed Activities* section. Impacts from sonar to reptiles within the Study Area would be limited to systems with energy below 2 kHz, primarily from low-frequency sonars but could also include some broadband and lower mid-frequency sources (less than 2 kHz). The use of these systems could occur throughout the Study Area but would be concentrated in the Hawaii Study Area and SOCAL Range Complex. Some low-frequency sonars could also be utilized in nearshore waters (e.g., San Clemente Island nearshore under training and Pearl Harbor under testing activities) though these systems are typically operated farther offshore. Overall, low-frequency sources are operated less often than higher frequency sources throughout the Study Area. Although the general impacts from sonar during testing would be similar in severity to those described during training, there is a higher quantity of sonar usage under testing activities and therefore there may be slightly more impacts during testing activities.

The most probable impacts from exposure to sonar is hearing loss, masking, behavioral reactions, and physiological response. Sonar-induced acoustic resonance and bubble formation phenomena are very unlikely to occur under realistic conditions, as discussed in the *Reptile Acoustic Background* section. Non-auditory injury and mortality from sonar are not possible under realistic exposure conditions. Any impact on hearing can reduce the distance over which a reptile detects environmental cues, such as the sound of waves, or the presence of a vessel or predator. A reptile could respond to sounds detected within its hearing range if it is close enough to the source. Use of sonar would typically be transient and temporary, and there is no evidence to suggest that any behavioral response would persist after a sound exposure. In addition, a stress response may accompany any behavioral response. Although masking of biologically relevant sounds by the limited number of sonars and other transducers operated in reptile hearing range is possible, this may only occur in certain circumstances. Reptiles most likely use sound to detect nearby broadband, continuous environmental sounds, such as the sounds of waves crashing on the beach. Reptiles may rely on senses other than hearing such as vision or magnetic orientation and could potentially reduce the effects of masking. The use characteristics of most low-frequency sonars include limited bandwidth, beam directionality, beam width, duration of use, and relatively low source levels and low duty cycle. These factors greatly limit the potential for a reptile to detect these sources and the potential for masking of broadband, continuous environmental sounds.

Conclusions regarding impacts from the use of sonars during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.2 Impacts from Air Guns

Air guns use bursts of pressurized air to create intermittent, broadband, impulsive sounds. Air gun use by the Navy is limited and is unlike large-scale seismic surveys that use an array with multiple air guns firing simultaneously or sequentially. Air gun use would occur nearshore in the SOCAL Range Complex under Intelligence, Surveillance, Reconnaissance testing activities, and greater than 3 NM from shore in the Hawaii, Northern and SOCAL Range Complexes under Acoustic and Oceanographic Research testing activities.

Sounds from air guns are impulsive, broadband, dominated by lower frequencies, and are within the hearing range of reptiles. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles. Potential impacts from air guns could include TTS, AINJ, behavioral reactions, physiological response, and masking. Ranges to auditory effects for reptiles exposed to air guns are in Section 3.4.2 (Range to Effects for Air Guns). The visual observation distances described in the *Mitigation* section are designed to avoid or substantially reduce the potential for AINJ due to air guns. As shown in Section 3.4.2 (Range to Effects for Air Guns), ranges to AINJ and TTS are relatively short. Furthermore, the mitigation zone (200 yds.) extends beyond these ranges and will help prevent or reduce any potential for AINJ and TTS in sea turtles.

Limited research and observations from air gun studies (see the *Reptile Acoustic Background* section) suggest that if reptiles are exposed to repetitive impulsive sounds in close-proximity, they may react by increasing swim speed, avoiding the source, or changing their position in the water column. There is no evidence to suggest that any behavioral response would persist after the sound exposure. Due to the low duration of an individual air gun shot, approximately 0.1 second, and the low duty cycle of sequential shots, the potential for masking from air guns would be low.

Conclusions regarding impacts from the use of air guns during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.3 Impacts from Pile Driving

Port Damage Repair training activities at Port Hueneme, California could occur throughout the year and are made up of multiple events, each which could occur up to 12 times per year. Each training events is comprised of up to seven separate modules, each which could occur up to three iterations during a single event (for a maximum of 21 modules). Training events would last a total of 30 days, of which pile driving is only anticipated to occur for a maximum of 14 days. Sound from pile driving activities could occur over several hours in each day, though breaks in pile driving are taken frequently to reposition the drivers between piles. Depending on where the activity occurs at Port Hueneme, transmission of pile driving noise may be reduced by pier structures. As a standard operating procedure, the Navy performs soft starts at reduced energy during an initial set of strikes from an impact hammer. Soft starts may “warn” reptiles and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Potential impacts did not consider any benefits from soft starts, nor was the possibility that reptiles could avoid the construction area.

Sounds from an impact hammer are impulsive, broadband, and dominated by lower frequencies. A vibratory hammer produces sounds that are similar in frequency range as the impact hammer, except the levels are much lower, especially when installing or extracting piles from soft substrate (i.e., sandy bottom), and the sound is continuous while operating. The sounds produced from impact and vibratory pile driving and removal are within the hearing range of reptiles. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles. Section 3.4.3 shows the predicted ranges to AINJ, TTS, and behavioral response for sea turtles from exposure to impact and vibratory pile driving. The mitigation zone (100 yds.) will help prevent or reduce any potential impacts on sea turtles.

The working group that prepared the *ANSI Sound Exposure Guidelines* (Popper et al., 2014) provide parametric descriptors of sea turtle behavioral responses to impact pile driving. Popper et al. (2014) estimate the risk of sea turtles responding to impact pile driving is high, moderate, and low while at near (tens of meters), intermediate (hundreds of meters), and far (thousands of meters) distances from the source, respectively. Based on prior observations of sea turtle reactions to sound, if a behavioral reaction were to occur, the responses can include increases in swim speed, change of position in the water column, or avoidance of the sound (see the *Reptile Acoustic Background* section). There is no evidence to suggest that any behavioral response would persist after a sound exposure, and it is likely that a stress response would accompany any behavioral response or TTS.

The vibratory hammer produces sounds that could cause some masking in reptiles, but the effect would be temporary, only lasting the duration that piles are driven or extracted. Due to the low source level of vibratory pile extraction, the zone for potential masking would only extend a few hundred meters from where the source is operating. For impact pile driving, the rate of strikes (60 per minute) has the potential to result in some masking. Port Hueneme is a military port with potentially high ambient noise levels due to vessel traffic and port activities. Given these factors, significant masking is unlikely to occur in reptiles due to exposure to sound from impact pile driving or vibratory pile driving/extraction.

If reptiles are exposed to sounds from pile driving or extraction, they could potentially react with short-term behavioral reactions and physiological (stress) responses (see the *Reptiles Acoustic Background* section).

Conclusions regarding impacts from pile driving activities during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.4 Impacts from Vessel Noise

Reptiles may be exposed to vessel-generated noise throughout the Study Area. Military readiness activities with vessel-generated noise would be conducted as described in the *Proposed Activities* section and *Activity Descriptions* sections. Specifically, Navy vessel traffic in Hawaii is heaviest south of Pearl Harbor, and in Southern California, Navy vessel traffic is heaviest around San Diego and roughly within 50 NM of shore, though these activities could occur throughout the Study Area, as described in the *Acoustic Habitat* section. The four amphibious approach lanes on the coast of central California bordering NOCAL and PSMR near Mill Creek Beach, Morro Bay, Pismo Beach, and Vandenberg Space Force Base are sources of nearshore vessel noise as well. Navy traffic also has clear routes from Hawaii to the Mariana Islands, Japan and San Diego, and from San Diego north to the Pacific Northwest. Vessel movements involve transits to and from ports to various locations within the Study Area, and many ongoing and proposed activities within the Study Area involve maneuvers by various types of surface ships, boats, and submarines (collectively referred to as vessels), as well as unmanned vehicles. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours up to two weeks. Surface combatant ships (e.g., destroyers, guided missile cruisers, and littoral combat ships) and submarines especially are designed to be quiet to evade enemy detection. Characteristics of vessel noise are described in the *Acoustic Habitat* section.

Due to the acoustic characteristics of vessel noise (i.e., moderate- to low-level source levels), vessel noise is unlikely to cause any direct injury. Furthermore, vessels are transient and would result in brief periods of exposure. Vessels produce continuous broadband noise within the hearing range of reptiles. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles.

Based on best available science summarized in the *Reptile Acoustic Background* section, potential impacts on reptiles include masking, behavioral reactions, and physiological response. Vessel source levels are below the sound levels that would cause hearing loss or AINJ. For louder vessels, such as Navy supply ships, reptiles would typically exhibit a brief startle and avoidance reaction if they react at all. Any of these reactions to vessels are not likely to disrupt important behavioral patterns. The size and severity of these impacts would be insignificant, and not rise to the level of measurable impacts. While it is likely that sea turtles may exhibit some behavioral response to vessels, numerous sea turtles bear scars that appear to have been caused by propeller cuts or collisions with vessel hulls that may have been exacerbated by a sea turtle surfacing reaction or lack of reaction to vessels (Hazel et al., 2007; Lutcavage et al., 1997).

Acoustic masking, especially from larger, non-combatant vessels, is possible. Vessels produce continuous broadband noise, with larger vessels producing sound that is dominant in the lower frequencies (as described in the *Acoustic Habitat* section) where reptile hearing is most sensitive. Smaller vessels emit more energy in higher frequencies, much of which would not be detectable by reptiles. Existing high ambient noise levels in ports and harbors with non-military vessel traffic and in shipping lanes with commercial vessel traffic would limit the potential for masking by military vessels in those areas. In offshore areas with lower ambient noise, the duration of any masking effects in a particular location would depend on the time in transit by a vessel through an area. Exposure to vessel noise could result in short-term behavioral reactions, physiological response, masking, or no response (see the *Reptile Acoustic Background* section). Impacts from vessel noise would be temporary and localized, and such responses would not be expected to compromise the general health or condition of individual reptiles. Therefore, long-term consequences for populations are not expected.

Conclusions regarding impacts from activities that produce vessel noise during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.5 Impacts from Aircraft Noise

Reptiles may be exposed to aircraft-generated noise throughout the Study Area. Military readiness activities with aircraft would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Both manned and unmanned fixed- and rotary-wing (e.g., helicopters) aircraft are used for a variety of military readiness activities throughout the Study Area. Tilt-rotor impacts would be like fixed-wing or rotary-wing aircraft impacts depending which mode the aircraft is in. Most of these sounds would be concentrated around airbases and fixed ranges within each of the range complexes. Aircraft noise can also occur in the waters immediately surrounding aircraft carriers at sea during takeoff and landing or directly below hovering rotary-wing aircraft that are near the water surface.

Aircraft produce extensive airborne noise from either turbofan or turbojet engines. An infrequent type of aircraft noise is the sonic boom, produced when the aircraft exceeds the speed of sound. Rotary-wing aircraft produce low-frequency sound and vibration (Pepper et al., 2003). Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors, but significant acoustic energy is primarily transmitted into the water directly below the aircraft in a narrow cone, as discussed in detail in the *Acoustic Primer* section.

Aircraft noise is within the hearing range of reptiles and activities that produce aircraft noise can occur in areas potentially inhabited by reptiles. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles.

In most cases, exposure of a reptile to fixed-wing aircraft presence and noise would be brief as the aircraft quickly passes overhead. Animals would have to be at or near the surface at the time of an overflight to be exposed to appreciable sound levels. Supersonic flight at sea is typically conducted at altitudes exceeding 30,000 ft., limiting the number of occurrences of supersonic flight being audible at the water's surface. Because most overflight exposures from fixed-wing aircraft or transiting rotary-wing aircraft would be brief and aircraft noise would be at low received levels, only startle reactions, if any, are expected in response to low altitude flights. Similarly, the brief duration of most overflight exposures would limit any potential for masking of relevant sounds, and reptiles may dive or move to a different area to reduce potential masking impacts (see the *Reptile Acoustic Background* section).

Daytime and nighttime activities involving rotary-wing aircraft may occur for extended periods of time, up to a couple of hours in some areas. During these activities, rotary-wing aircrafts would typically transit throughout an area and may hover over the water. Longer duration activities and periods of time where rotary-wing aircraft hover may increase the potential for behavioral reactions, startle reactions, and stress. Low-altitude flights of rotary-wing aircraft during some activities, which often occur under 100 ft. altitude, may elicit a stronger startle response due to the proximity of a rotary-wing aircraft to the water; the slower airspeed and longer exposure duration; and the downdraft created by a rotary-wing aircraft's rotor. Most fixed-wing aircraft and rotary-wing aircraft activities are transient in nature, although rotary-wing aircraft can also hover for extended periods. The likelihood that a reptile would occur or remain at the surface while an aircraft transits directly overhead would be low. Rotary-wing aircraft that hover in a fixed location for an extended period can increase the potential for exposure. However, impacts from military readiness activities would be highly localized and concentrated in space and duration.

Reptiles may respond to both the physical presence and to the noise generated by aircraft, making it difficult to attribute causation to one or the other stimulus. In addition to noise produced, all low-flying aircraft make shadows, which can cause animals at the surface to react. Rotary-wing aircraft may also produce strong downdrafts, a vertical flow of air that becomes a surface wind, which can also affect an animal's behavior at or near the surface. The amount of sound entering the ocean from aircraft would be very limited in duration, sound level, and affected area. Overall, if reptiles were to respond to aircraft noise, only short-term behavioral or physiological response would be expected. Therefore, impacts on individuals would be unlikely and long-term consequences for populations are not expected.

Conclusions regarding impacts from activities that produce aircraft noise during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.6 Impacts from Weapons Noise

Reptiles may be exposed to sounds caused by the firing of weapons, objects in flight, and inert impact of non-explosive munitions on the water surface. Military readiness activities using weapons and deterrents would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. The locations where gunnery and other munitions may be used are shown in the *Munitions* data section. Most weapons noise is attributable to Gunnery activities. The overall proposed use of large caliber gunnery has decreased since the prior analysis, whereas medium caliber gunnery would be similar. Most activities involving large caliber naval gunfire or other munitions fired or launched from a vessel are conducted more than 12 NM from shore. The Action Proponents will implement mitigation to avoid or reduce potential impacts from weapon firing noise during Large-Caliber Gunnery activities, as discussed in the *Mitigation* section. For explosive munitions, only associated firing noise is considered in the analysis of weapons noise. The noise produced by the detonation of explosive weapons is analyzed separately.

In general, weapons noise includes impulsive sounds generated in close vicinity to or at the water surface, except for items that are launched underwater, and are within the hearing range of reptiles. Weapons noise would be brief, lasting from less than a second for a blast or inert impact, to a few seconds for other launch and object travel sounds. As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles.

Most incidents of impulsive sounds produced by weapon firing, launch, or inert object impacts would be single events. Activities that have multiple detonations such as some naval gunfire exercises could create some masking for reptiles in the area over the short duration of the event. It is expected that these sounds may elicit brief startle reactions or diving, with avoidance being more likely with the repeated exposure to sounds during gunfire events. It is likely that reptile behavioral responses would cease following the exposure event, and the risk of a corresponding sustained stress response would be low. Similarly, exposures to impulsive noise caused by these activities would be so brief that risk of masking relevant sounds would be low. These activities would not typically occur in nearshore habitats where reptiles may use their limited hearing to sense broadband, coastal sounds. Behavioral reactions, startle reactions, and physiological response due to weapons noise are likely to be brief and minor, if they occur at all due to the low probability of co-occurrence between weapon activity and individual reptiles.

Sound due to missile and target launches is typically at a maximum at initiation of the booster rocket and rapidly fades as the missile or target travels downrange. These sounds would be transient and of short duration, lasting no more than a few seconds at any given location. Many missiles and targets are launched from aircraft, which would produce minimal noise in the water due to the altitude of the aircraft at launch. Missiles and targets launched by ships or near the water surface may expose reptiles to levels of sound that could produce brief startle reactions, avoidance, or diving. Due to the short-term, transient nature of launch noise, animals are unlikely to be exposed multiple times within a short period. Reactions by reptiles to these specific stressors have not been recorded; however, reptiles would be expected to react to weapons noise as they would other transient sounds. Behavioral reactions would likely be short term (minutes) and are unlikely to lead to long-term consequences for individuals or species.

Conclusions regarding impacts from activities that produce weapons noise during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.1.7 Impacts from Explosives

Reptiles may be exposed to sound and energy from explosions in the water and near the water surface associated with the proposed activities. Activities using explosives would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Most explosive activities would occur in the SOCAL Range Complex, the Hawaii Range Complex, and PMSR, although activities with explosives would also occur in other areas as described in the *Activity Descriptions* section. Most activities involving in-water explosives associated with large caliber naval gunfire, or the launching of targets, missiles, bombs, or other munitions, are conducted more than 12 NM from shore. Small Ship Shock Trials could occur in the SOCAL Range Complex greater than 12 NM from shore as shown in the *Proposed Activities* section. Sinking Exercises are conducted greater than 50 NM from shore as shown in the *Proposed Activities* section. Certain activities with explosives may be conducted close to shore at locations identified in the Activity Descriptions section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS.

This includes certain Mine Warfare and Expeditionary Warfare activities. In the Hawaii Range Complex explosive activities could occur at specified ranges and designated locations around Oahu, including the Puuloa Underwater Range and designated locations in and near Pearl Harbor. In the SOCAL Range Complex, explosive activities could occur near San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast.

Characteristics, quantities, and net explosive weights of in-water explosives used during military readiness activities are provided in the *Acoustic Stressors* section. The use of in-water explosives would increase from the prior analysis for training activities and would decrease slightly for testing. There is an overall reduction in the use of most of the largest explosive bins (bin E8 [> 60–100 pounds (lb.) net explosive weight (NEW)] and above) for training, and a decrease in two of the largest explosive bins (bin E10 [> 250–500 lb. NEW] and E11 [> 500–650 lb. NEW]) under testing activities. There would be notable increases in the smaller explosive bins (E7 [> 20–60 lb. NEW] and below) under training and testing activities, except for bin E1 (0.1–0.25 lb. NEW) which would decrease under testing activities. Small Ship Shock Trials (bin E16 [> 7,250–14,500 lb. NEW]) not previously analyzed are currently proposed under testing activities. Although the general impacts from explosives during training would be similar in severity to those described during testing, there is a higher quantity of explosives used under training activities and therefore there may be slightly more impacts.

The types of activities with detonations below the surface include Mine Warfare, activities using explosive torpedoes, and ship shock trials, as well as specific training and testing activities. Most explosive munitions used during military readiness activities, however, would occur at or just above the water surface (greater than 90 percent by count). These include those used during surface warfare activities, such as explosive gunnery, bombs, and missiles. Certain nearshore activities use explosives in the surf zone up to the beach, where most explosive energy is released in the air (refer to Appendix H, Description of Systems and Ranges, for location details). In the below quantitative analysis, impacts on reptiles are over-estimated because in-air near surface and surf zone explosions are modeled as underwater explosions, with all energy assumed to remain in the water. Sound and energy from in-air detonations at higher altitudes would be reflected at the water surface and therefore are not analyzed further in this section and would have no effect on reptiles.

Characteristics, quantities, and net explosive weights of in-water explosives used during military readiness activities are provided in the *Acoustic Stressors* section. Explosives produce loud, impulsive, broadband sounds. Potential impacts from exposures to explosives are discussed in the *Reptile Acoustic Background* section and include masking, behavioral reactions, hearing loss, AINJ, non-auditory injury, and mortality. Estimated behavioral reactions, auditory impacts, non-auditory impacts, and mortality were modeled. Impact ranges for reptiles exposed to explosive sound and energy are shown in Section 3.4.4 (Range to Effects for Explosives). As discussed in the *Mitigation* section, the Action Proponents will implement mitigation to relocate, delay, or cease detonations when a sea turtle is sighted within or entering a mitigation zone to avoid or reduce potential explosive impacts. The visual observation distances described in the *Mitigation* section are designed to cover the distance to mortality and reduce the potential for injury due to explosives.

As discussed in the *Reptile Acoustic Background* section, sea turtles and sea snakes have similar hearing capabilities, mechanisms, and likely usage. Therefore, the types of impacts on sea snakes are assessed to be comparable to those for sea turtles. Impacts including TTS, AINJ, and non-auditory injury can reduce the fitness of an individual animal, causing a reduction in foraging success, reproduction, or increased susceptibility to predators. This reduction in fitness would be temporary for recoverable impacts, such as TTS. There may be long-term consequences to some individuals, however, no population-level impact is expected due to the low number of potential injuries or mortalities for any reptile species relative to total population size. Recovery from a hearing threshold shift begins almost immediately after the noise exposure ceases. Full recovery from a temporary threshold shift is expected to take a few minutes to a few days, depending on the severity of the initial shift (see *Criteria and Thresholds TR*). If any hearing loss remains after recovery, that remaining hearing threshold shift is permanent. Because explosions produce broadband sounds with low-frequency content, hearing loss due to explosive sound could occur across a reptile's hearing range, reducing the distance over which relevant sounds may be detected for the duration of the threshold shift.

A reptile's behavioral response to a single detonation or explosive cluster is expected to be limited to a short-term startle response or other behavioral responses, as the duration of noise from these events is very brief. Limited research and observations from air gun studies (see the *Reptile Acoustic Background* section) suggest that if sea turtles are exposed to repetitive impulsive sounds in close-proximity, they may react by increasing swim speed, avoiding the source, or changing their position in the water column. There is no evidence to suggest that any behavioral response would persist after the sound exposure. Because the duration of most explosive events is brief, the potential for masking is low. The *ANSI Sound Exposure Guidelines* (Popper et al., 2014) consider masking to not be a concern for sea turtles exposed to explosions and is also likely the case for sea snakes.

A physiological response is likely to accompany any injury, hearing loss, or behavioral reaction. A stress response is a suite of physiological changes that are meant to help an organism mitigate the impact of a stressor. While the stress response is a normal function for an animal dealing with natural stressors in their environment, chronic stress responses can reduce an individual's fitness. However, explosive activities are generally displaced over space and time and would not likely result in repeated exposures to individuals over a short period of time (hours to days).

Conclusions regarding impacts from the use of explosives during military readiness activities for ESA-listed species are provided in Section 3.3 (ESA-Listed Species Impact Assessments).

3.2 Quantifying Impacts on Reptiles from Acoustic and Explosive Stressors

The following section provides an overview of key components of the modeling methods used to quantify impacts in this analysis. As a note, the quantitative impact analyses below are only performed for sea turtles. The following technical reports go into more detail on the quantitative process and show specific data inputs to the models.

- The modeling methods used to quantify impacts are described in detail in the *Quantitative Analysis TR*. Impacts due to sonar, air guns, and explosives were quantified using the Navy Acoustic Effects Model. Impacts due to pile driving were modeled outside of the Navy Acoustic Effects Model using a static area-density model.
- The development of criteria and thresholds used to predict impacts is shown in the *Criteria and Thresholds TR.*
- The spatial density models for each sea turtle species are described in the *Density TR*. The density models have been updated with new data since the prior analysis. The density technical report includes figures that show a species-by-species comparison (where applicable) of the density estimates used in the prior analysis to the updated estimates used for the current analysis. Areas

where densities changed are characterized as either no to minimal change, an increase, or a decrease.

- The dive profile for each species is shown in *the Dive Profile TR*. There are no substantive changes from the prior analysis.

3.2.1 The Navy's Acoustic Effects Model

The Navy Acoustic Effects Model was developed by the Navy to conduct a comprehensive acoustic impact analysis for use of sonars, air guns, and explosives in the marine environment. This model considers the physical environment, including bathymetry, seafloor composition/sediment type, wind speed, and sound speed profiles, to estimate propagation loss. The propagation information combined with data on the locations, numbers, and types of military readiness activities and marine resource densities provides estimated numbers of effects to each stock.

Individual sea turtles are represented as "animats," which function as dosimeters and record acoustic energy from all active underwater sources during a simulation of a training or testing event. Each animat's depth changes during the simulation according to the typical depth pattern observed for each species. During any individual modeled event, impacts on individual animats are considered over 24-hour periods.

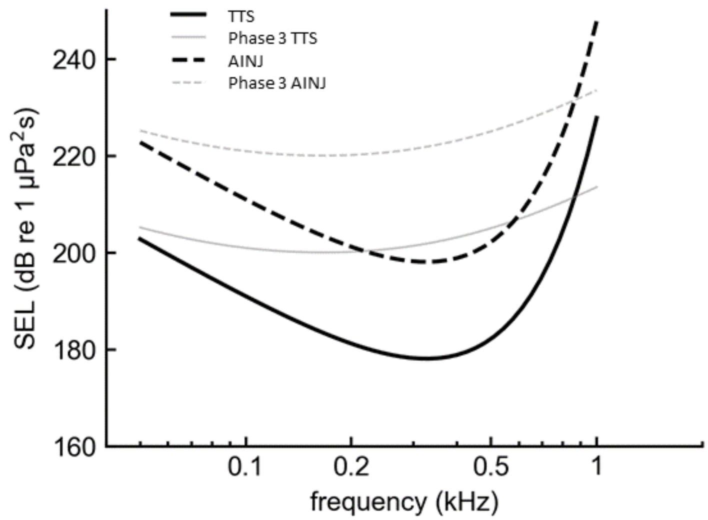
Because limited data are available on sea snake hearing, and most activities using acoustic substressors and explosives would not occur in sea snake habitat, impacts on sea snakes due to military readiness activities are qualitatively analyzed.

The model estimates the number of instances in which an effect threshold was exceeded over the course of a year, it does not estimate the number of times an individual in a population may be impacted over a year. Some sea turtles may be impacted multiple times, while others may not experience any impact.

3.2.2 Quantifying Impacts on Hearing

The auditory criteria and thresholds used in this analysis have been updated since the prior assessment of impacts due to military readiness activities in the Study Area. The auditory criteria and thresholds used in this analysis incorporate the latest and best available science and is discussed in the *Criteria and Thresholds TR*.

The best way to illustrate frequency-dependent susceptibility to auditory effects is an exposure function. Exposure functions for TTS and AINJ incorporate both the shape of the auditory weighting function and its weighted threshold value for either TTS or AINJ. Exposure functions that are updated for this analysis are shown in Figure 3.2-1.



Note: TTS = temporary threshold, AINJ = auditory injury.

Figure 3.2-1: Sea Turtle Exposure Function for Non-Impulsive TTS and AINJ

Estimated auditory impacts increased due to the following changes to the TTS and AINJ thresholds:

- The weighted non-impulsive SEL thresholds decreased by 22 dB (re 1 $\mu Pa^2 s$).
- The weighted impulsive SEL thresholds decreased by 20 dB (re 1 $\mu Pa^2 s$).
- The impulsive peak SPL thresholds decreased by 2 dB (re 1 µPa).

Table 3.2-1 lists the values for all auditory impact thresholds. For a detailed description of how these thresholds were determined, see the *Criteria and Thresholds TR*.

In contrast to the prior analysis, sea turtle avoidance of repeated high-level exposures from sonar was not applied in this analysis.

Table 3.2-1: Phase 3 and Phase 4 TTS and AINJ Onset Levels for Sonar (Non-Impulsive) and Explosive (Impulsive) Sound Sources in Sea Turtles.

	Phase 3		Phase 4	
	TTS	AINJ	TTS	AINJ
Non-impulsive onset SEL (dB re 1 $\mu Pa^2 s$ weighted)[1]	200	220	178	198
Impulsive onset SEL (dB re 1 $\mu Pa^2 s$ weighted) [1]	189	204	169	184
Impulsive onset Peak SPL (dB re 1 µPa)	226	232	224	230

Note: TTS = temporary threshold, AINJ = auditory injury, SEL = sound exposure level, SPL = sound pressure level.
[1]The weighted non-impulsive thresholds by themselves only indicate the TTS/AINJ threshold at the most susceptible frequency (the exposure function shape for non-impulsive sources is shown in Figure 3.2-1).

3.2.3 Quantifying Behavioral Impacts

The behavioral thresholds for sonars, air guns, and pile driving are the same as the prior assessment of impacts due to military readiness activities in the Study Area and is discussed in the *Criteria and Thresholds TR*. For exposures to single and multiple explosions, SEL-based thresholds were developed that are consistent with how marine mammal behavioral response thresholds were developed for exposures to single and multiple explosions. Table 3.2-2 lists the behavioral response thresholds for sea turtles used in this analysis.

Table 3.2-2: Behavioral Response Thresholds for Sea Turtles

Source	dB SPL rms (unweighted)	dB SEL (cumulative; weighted)
Air guns	175	-
Pile driving	175	-
Sonar ≤ 2 kHz	175	-
Explosives[1]	-	164

Note: SPL = sound pressure level, SEL = sound exposure level, rms = root mean square. Weighted cumulative SEL thresholds in dB re 1 μPa^{2}s and unweighted SPL rms thresholds in dB re 1 μPa. The root mean square and sound exposure level calculations are based on the duration defined by the 5% and 95% points along the cumulative energy curve and captures 90% of the cumulative energy in the impulse.
[1]For a single explosion the behavioral response threshold is set to the impulsive TTS onset threshold of 169 dB re 1 μPa^{2}s SEL

3.2.4 Quantifying Non-Auditory Injury due to Explosives

The criterion for mortality is based on severe lung injury derived from Goertner (1982) and the criteria for non-auditory injury are based on slight lung injury or gastrointestinal tract injury. Mortality and slight lung injury impacts on sea turtles will be predicted using thresholds for both juvenile and adult weights (see *Criteria and Thresholds TR*). An additional criterion for non-auditory injury is onset of gastrointestinal tract injury, which is the same for all species and age classes for explosive impacts. The onset (i.e., 1%) thresholds will be used to calculate impacts and model ranges to effect to inform mitigation assessment. This differs from the prior analysis where the 50% criterion (the level at which 50% of animals would be expected to have the response) was used to estimate the number of mortalities and non-auditory injuries. The updated threshold is more conservative (i.e., overpredicts numbers of effects) and will result in a small increase in the predicted non-auditory injuries and mortalities for the same event compared to prior analyses. Thresholds are provided in Table 3.2-3 for use in non-auditory injury assessment for sea turtles exposed to underwater explosives.

Table 3.2-3: Thresholds for Estimating Ranges to Potential Effect for Non-Auditory Injury.

Onset effect for mitigation consideration	Threshold
Onset Mortality - Impulse	$103M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Impulse (Non-auditory)	$47.5M^{1/3}\left(1+\frac{D}{10.1}\right)^{1/6}$ Pa-s
Onset Injury - Peak Pressure (Non-auditory)	237 dB re 1 μPa peak

Note: M is animal mass (kg), and D is animal depth (m).

3.3 ESA-Listed Species Impact Assessments

The following sections analyze impacts on reptiles under the Proposed Action and show model-predicted estimates of take for sea turtles. The methods used to quantify impacts for each substressor are described above in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives). The methods used to assess significance of individual impacts and risks to reptiles are described above in Section 3.2 (Quantifying Impacts on Reptiles from Acoustic and Explosive Stressors). For each sea turtle species, a multi-sectioned table (Table 3.3-1 through Table 3.3-6) quantifies impacts as follows:

Section 1

The first section shows the number of instances of each effect type that could occur due to each substressor (sonar, air guns, or explosives) over a maximum year of activity. Impacts are shown by type of activities (training excluding the U.S. Coast Guard, U.S. Coast Guard training activities only, or testing activities).

The number of instances of effect is not the same as the number of individuals that could be affected, as some individuals could be affected multiple times, whereas others may not be affected at all. The instances of effect are those predicted by the Navy's Acoustic Effects Model and are not further reduced to account for activity-based mitigation that would reduce effects near some sound sources and explosives as described in the *Mitigation* section.

In the modeling, instances of effect are calculated within 24-hour periods of each individually modeled event. Impacts are assigned to the highest order threshold exceeded at the animat, which is a dosimeter in the model that represents an animal of a particular species. Non-auditory injuries are assumed to outrank auditory effects, and auditory effects are assumed to outrank behavioral responses. In all instances, any auditory impact or injury are assumed to represent a concurrent behavioral response. For example, if a behavioral response and TTS are predicted for the same animat in a modeled event, the effect is counted as a TTS in the table.

For most activities, total impacts are based on multiplying the average expected impacts at a location by the number of times that activity is expected to occur. This is a reasonable method to estimate impacts for activities that occur every year and multiple times per year. There are two exceptions to that approach in this analysis: Civilian Port Defense (a training activity using sonar) and Small Ship Shock Trial (a testing activity using explosives). These two activities do not occur every year, have a very small number of total events over seven years, and could occur at one of many locations. Notably, Civilian Port Defense is the only proposed activity at certain port locations. Instead of using averaged impacts across locations for these two activities, the maximum impacts on any species at any of the possible locations is used. While this approach results in unrealistically high estimates of impacts for some species for these two activities, it ensures that this analysis appropriately assesses potential impacts where these rare events may occur.

The summation of instances of effect includes all fractional values caused by averaging multiple modeled iterations of individual events. Impacts are only rounded to whole numbers at the level of substressor and type of activities. Rounding follows standard rounding rules, in which values less than 0.5 round down to the lower whole number, and values equal to or greater than 0.5 round up to the higher whole number. A zero value (0) indicates that the sum of impacts is greater than true zero but less than 0.5. A dash (-) indicates that no impacts are predicted (i.e., a "true" zero). This would occur when there is no overlap of an animat in the modeling with a level of acoustic exposure that would result in any possibility of take during any activity. Non-auditory injury and mortality are only associated with use of explosives; thus, these types of effects are also true zeroes for any other acoustic substressor. A one in parentheses (1) indicates that predicted impacts round to zero in a maximum year of activity, but a single impact is predicted over seven years when summing the fractional risks across years. This is explained further below.

The summation of impacts across seven years is shown in Section 3.3.6 (Impact Summary Tables). The seven-year sum accounts for any variation in the annual levels of activities. The seven-year sum includes any fractional impact values predicted in any year, which is then rounded following standard rounding rules. That is, the seven-year impacts are not the result of summing the rounded annual impacts. If a seven-year sum was larger than the annual impacts multiplied by seven, the annual maximum impacts were increased by dividing the seven-year sum of impacts by seven then rounding up to the nearest integer. For example, this could happen if maximum annual impacts are 1.34 (rounds to 1 annually) and seven-year impacts are 8.60 (rounds to 9), where 9 divided by 7 years (9 ÷ 7 = 1.29) is greater than the estimated annual maximum of 1. In this instance, the maximum annual impacts would be adjusted from one to two based on rounding up 1.29 to 2. In multiple instances, this approach resulted in increasing the maximum annual impacts predicted by the Navy's Acoustic Effects Model.

Section Two

The second section shows the percent of total impacts that would occur within seasons and general geographic areas. The general geographic areas are SOCAL, PMSR, NOCAL, HRC, and the high seas (transit lanes between the California and Hawaii portions of the Study Area).

Section Three

The third section shows which activities are most impactful to a stock. Activities that cause five percent or more of total impacts on a species are shown.

Section Four (when applicable)

The fourth section shows impacts in critical habitats where they are designated for ESA-listed species. If a species does not have designated ESA critical habitat in the Study Area, then Section 4 (Impacts on Fishes from Acoustic and Explosive Stressors) is not shown in the tables.

3.3.1 GREEN SEA TURTLE (*CHELONIA MYDAS*) - THREATENED

Green sea turtles from the Central North Pacific and East Pacific Ocean distinct population segments (DPS) are in the Study Area and are ESA-listed as threatened. There is no critical habitat designated for the green sea turtle in the Study Area, but critical habitat has been proposed by NMFS (88 FR 46376). Model-predicted impacts are presented in Table 3.3-1 and Table 3.3-2.

Hatchling and post-hatchling green sea turtles occur in offshore open ocean areas where they forage and develop in floating algal mats. Juvenile green sea turtles leave the open-ocean habitat and retreat to protected lagoons and open coastal areas that are rich in seagrass or marine algae, where they spend most of their lives. Green sea turtles likely to occur in the Study Area come from eastern Pacific Ocean and Hawaiian nesting populations. Some green turtles nesting on beaches in Mexico forage in the waters off California, thus requiring migration to complete their life cycle. Green sea turtles nest on beaches within the Hawaii Range Complex, and feed and migrate throughout all waters of the Study Area. In the SOCAL Range complex they occur predominantly in coastal and inshore waters.

Green sea turtles from the Central North Pacific and East Pacific Ocean DPS may be exposed to sonar, air guns, vessel noise, aircraft noise, weapons noise, and explosives associated with military readiness activities throughout the year. Green sea turtles would not overlap with pile driving activities in Port Hueneme, therefore, impacts from pile driving to green sea turtles are not further analyzed. Analysis of the impacts from vessel noise, aircraft noise, and weapons noise on green turtles relies on the information under the respective acoustic substressor in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives).

Results from the Navy Acoustics Effects Model (Table 3.3-1 and Table 3.3-2) shows that green sea turtles in the Study Area may exhibit behavioral reactions, TTS, and AINJ from sonar, air guns, and explosives, and non-auditory injury and mortality from explosives over the course of a year.

For the East Pacific DPS of green sea turtles, the largest contributor of impacts from sonar are due to Acoustic and Oceanographic Research testing activities, with more impacts during the cold season. Impacts from air gun use are due to Acoustic and Oceanographic Research for testing activities with impacts occurring equally during the warm and cold seasons. The largest contributors of impacts from explosives are Underwater Demolition Qualification and Certification for training activities and Mine Countermeasure and Neutralization testing activities, with more impacts during the cold season. No impacts on the East Pacific DPS of green sea turtles are estimated to occur within proposed critical habitat.

For the Central North Pacific DPS of green sea turtles, the largest contributors of impacts from sonar are Acoustic and Oceanographic Research testing activities, with slightly more impacts during the warm season. Impacts from air gun use are due to Acoustic and Oceanographic Research testing activities with impacts during the cold season only. The largest contributor of impacts from explosives is Obstacle Loading for training activities, with more impacts during the warm season, and Underwater Demolition Qualification and Certification for training activities with more impacts during the warm season. Overall, most BEH, TTS, AINJ, and non-auditory injury impacts on the Central North Pacific DPS of green sea turtles are estimated to occur within proposed critical habitat. The largest contributor of impacts in proposed critical habitat is from the use of explosives during Obstacle Loading training activities during the warm season.

At the PMRF on Kauaʻi, Hawaii, green sea turtles from the Central North Pacific DPS utilize the beaches of PMRF for nesting and the nearshore waters for foraging. Activities that could impact green sea turtles include vessel noise (from amphibious landings) and weapons noise (from launches and live-fire training exercises). Standard operating procedures are implemented for these activities and include surveying beaches one hour prior to landings and launches, and in the event a sea turtle is observed basking on the beach, activities would be delayed until the animal leaves on its own accord. Beaches will also be surveyed for sea turtle nests, and if found, will be marked and avoided. Implementation of these measures would limit potential impacts which are likely to be temporary (lasting up to several hours) or short term (lasting several days to several weeks) and could include behavioral response, TTS, and AINJ.

Estimated behavioral and TTS impacts from sonar, air guns, and explosives are expected to be short term and would not result in substantial changes to behavior, growth, survival, annual reproductive success, lifetime reproductive success, or species recruitment, for an individual and would not result in population-level impacts. Low levels of estimated AINJ from sonar and explosives, and injuries and mortalities from explosives may have deleterious effects on the fitness of an individual turtle but are not expected to impact the fitness of enough individuals to cause population level effects.

Based on the analysis presented above, the use of sonars and activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> green sea turtles in the East Pacific DPS. The use of explosives during training activities <u>may affect, and are likely to adversely affect,</u> green sea turtles in the East Pacific DPS. Activities that involve the use of pile driving are *not applicable to green sea turtles in the East Pacific DPS because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.*

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, green sea turtles in the East Pacific DPS. The use of sonars, air guns, and explosives during testing activities may affect, and are likely to adversely affect, green sea turtles in the East Pacific DPS. Pile diving activities are not conducted during testing.

Based on the analysis presented above, the use of sonars and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, green sea turtles in the Central North Pacific DPS. The use of explosives during training activities may affect, and are likely to adversely affect, green sea turtles in the Central North Pacific DPS. Activities that involve the use of pile driving are not applicable to green sea turtles in the Central North Pacific DPS because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, green sea turtles in the Central North Pacific DPS. The use of sonars, air guns, and explosives during testing activities may affect, and are likely to adversely affect, green sea turtles in the Central North Pacific DPS. Pile diving activities are not conducted during testing.

Critical Habitat

Green turtle critical habitat proposed by NMFS is along the coasts of California and the Hawaiian Archipelago. It is comprised of three different habitat types which are reproductive (Central North Pacific DPS only), migratory (East Pacific DPS only), and benthic foraging/resting. Pile driving activities in Port Hueneme do not overlap with any proposed critical habitat types. The impacts on these habitats would be considered insignificant, with no discernible effect on the conservation function of the physical and biological features.

The use of sonar, air guns, and explosives, and activities that produce vessel, aircraft, and weapons noise have a pathway to impact the physical and biological features of the reproductive and migratory portions of the proposed critical habitat from the mean high-water line to 20 m depth and the mean-high water line to 10 km offshore respectively. Activities that use sonars, air guns, and explosives, and activities that produce vessel noise, aircraft noise, and weapons noise are typically transient, and most sonar sources are outside of sea turtle hearing range which is most sensitive from 100–400 Hz and limited over 1 kHz. For reproductive habitat, training and testing activities would not obstruct nearshore waters adjacent to nesting beaches in the Hawaiian Archipelago, which are proposed as critical habitat by USFWS, for transit, mating, or internesting. For migratory habitat, activities would not restrict transit between benthic foraging/resting areas including North San Diego Bay and 10 km offshore, and reproductive areas from the Mexico border. The physical and biological features of benthic foraging/resting habitat from the mean high-water line to 20 m depth are underwater refugia and food resources of sufficient condition, distribution, diversity, abundance, and density to support survival, development, growth, and/or reproduction. The physical and biological features of benthic foraging/resting habitat would not be impacted by the sound from the use of sonars, air guns, and explosives, and activities that produce vessel, aircraft, and weapons noise.

The use of sonars and explosives, and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, proposed critical habitat for green sea turtles in the East Pacific DPS. Activities that involve the use of pile driving are not applicable to green sea turtle critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.

The use of sonars, air guns, and explosives, and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, proposed critical habitat for green sea turtles in the East Pacific DPS. Pile diving activities are not conducted during testing.

The use of sonars and explosives, and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, proposed critical habitat for green sea turtles in the Central North Pacific DPS. Activities that involve the use of pile driving are not applicable to green sea turtle critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.

The use of sonars, air guns, and explosives, and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, proposed critical habitat for green sea turtles in the Central North Pacific DPS. Pile diving activities are not conducted during testing.

Table 3.3-1: Estimated Effects to Green Sea Turtles (East Pacific DPS) over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	-	(1)	-	-	-
Explosive	Navy Training	9	8	1	(1)	0
Explosive	Navy Testing	2	7	1	0	0
Sonar	Navy Testing	29	552	7	-	-
Maximum Annual Total		**40**	**568**	**9**	**1**	**0**

Season	Percent of Total Effects SOCAL
Warm	38%
Cold	62%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Acoustic and Oceanographic Research (ONR)	Navy Testing	90%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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Table 3.3-2: Estimated Effects to Green Sea Turtles (Central North Pacific DPS) over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Air gun	Navy Testing	-	(1)	-	-	-
Explosive	Navy Training	2,019	1,061	41	2	1
Explosive	Navy Testing	32	58	4	(1)	0
Explosive	Army Training	(1)	(1)	-	-	-
Sonar	Navy Testing	15	45	0	-	-
Maximum Annual Total		**2,067**	**1,166**	**45**	**3**	**1**
	Percent of Total Effects					

Source	Category	BEH	TTS	AINJ	INJ	MORT
Season			**HRC**			
Warm			53%			
Cold			47%			

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Obstacle Loading	Navy Training	83%
Underwater Demolition Qualification and Certification	Navy Training	8%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	Critical Habitat (All)	1,636	950	39	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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3.3.2 HAWKSBILL SEA TURTLE (*ERETMOCHELYS IMBRICATA*) - ENDANGERED

Hawksbill sea turtles are ESA-listed as endangered throughout their range with no designated DPSs. There is no critical habitat designated for the hawksbill sea turtle in the Study Area. Model-predicted impacts are presented in Table 3.3-3.

The hawksbill sea turtle is the most tropical of the world's sea turtles, rarely occurring above 35° N or below 30° south (Witzell, 1983) and therefore they only occur in the Hawaii Study Area and High Seas portions of the Study Area. After hatching, hawksbill sea turtles migrate to pelagic habitats where they take shelter in floating algal mats. After 1 to 5 years, juveniles migrate to shallower coastal feeding grounds, including their preferred coral reef habitats, where they mature to adulthood and spend the remainder of their lives. Within the Study Area, nesting occurs only in the Hawaiian Islands, with known nesting activities only at Hawaii, Maui, and Molokai Islands (Brunson et al., 2022). The Hawaiian population of hawksbills migrate relatively short distances and stay within the island chain.

Hawksbill sea turtles may be exposed to sonar, air guns, vessel noise, aircraft noise, weapons noise, and explosives associated with military readiness activities throughout the year. Pile driving activities in Port Hueneme do not overlap with hawksbill sea turtle presence in the Hawaii Study Area and High Seas portions of the Study Area. Analysis of the impacts from vessel noise, aircraft noise, and weapons noise on hawksbill sea turtles relies on the information under the respective acoustic substressor in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives).

Results from the Navy Acoustics Effects Model (Table 3.3-3) shows that hawksbill sea turtles in the Study Area may exhibit behavioral reactions, TTS, and AINJ from sonar and explosives over the course of a year. No impacts were estimated to occur from the use of air guns during training activities.

For hawksbill sea turtles, the largest contributor of impacts from sonar are due to Acoustic and Oceanographic Research for testing activities, with more impacts during the warm season. The largest contributor of impacts from explosives are due to Obstacle Loading for training activities, with more impacts during the warm season, and Underwater Demolition Qualification and Certification for training activities with more impacts during the warm season.

Estimated behavioral and TTS impacts from sonar and explosives are expected to be short term and would not result in substantial changes to behavior, growth, survival, annual reproductive success, lifetime reproductive success, or species recruitment, for an individual and would not result in population-level impacts. Low levels of estimated AINJ from explosives may have deleterious effects on the fitness of an individual turtle but are not expected to impact the fitness of enough individuals to cause population level effects.

Based on the analysis presented above, the use of sonars and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, hawksbill sea turtles. The use of explosives during training activities may affect, and are likely to adversely affect, hawksbill sea turtles. Activities that involve the use of pile driving are not applicable to hawksbill sea turtles because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, hawksbill sea turtles. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, hawksbill sea turtles. Pile diving activities are not conducted during testing.

Table 3.3-3: Estimated Effects to Hawksbill Sea Turtles over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	18	10	(1)	-	-
Explosive	Navy Testing	0	1	0	-	-
Explosive	Army Training	-	(1)	-	-	-
Sonar	Navy Testing	1	6	0	-	-
Maximum Annual Total		**19**	**18**	**1**	**-**	**-**

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	56%	0%
Cold	42%	1%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Obstacle Loading	Navy Training	69%
Acoustic and Oceanographic Research (ONR)	Navy Testing	16%
Underwater Demolition Qualification and Certification	Navy Training	7%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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3.3.3 Loggerhead Sea Turtle (*Caretta caretta*) - Endangered

Loggerhead sea turtles from the North Pacific Ocean DPS are in the Study Area and are ESA-listed as endangered throughout their range. There is no critical habitat designated for the loggerhead sea turtle in the Study Area. Model-predicted impacts are presented in Table 3.3-4.

Loggerhead sea turtles occur in U.S. waters in habitats ranging from coastal estuaries to waters far beyond the continental shelf (Dodd, 1988; Martin et al., 2020). The species can be found hundreds of kilometers out to sea, as well as in inshore areas, such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Coral reefs, rocky areas, and shipwrecks are often used as feeding areas. The nearshore zone provides crucial foraging habitat, as well as habitat during the nesting season and overwintering habitat. Offshore, juvenile loggerheads forage in or migrate through the North Pacific Subtropical Gyre as they move between North American developmental habitats and nesting beaches in Japan. The highest densities of loggerheads can be found just north of Hawaii in the North Pacific Transition Zone (Briscoe et al., 2021; Polovina et al., 2000). The loggerhead sea turtle does not nest on Southern California beaches but is known to forage off the coast of the BCPM and may occur offshore of Southern California during anomalously warm water temperatures.

Loggerhead sea turtles may be exposed to sonar, air guns, vessel noise, aircraft noise, weapons noise, and explosives associated with military readiness activities throughout the year. Loggerhead sea turtles would not overlap with pile driving activities in Port Hueneme, therefore, impacts from pile driving to loggerhead sea turtles are not further analyzed. Analysis of the impacts from vessel noise, aircraft noise, and weapons noise on loggerhead sea turtles relies on the information under the respective acoustic substressor in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives).

Results from the Navy Acoustics Effects Model (Table 3.3-4) shows that loggerhead sea turtles in the Study Area may exhibit behavioral reactions, TTS, and AINJ from sonar and explosives, and non-auditory injury from explosives over the course of a year. No impacts were estimated to occur from the use of air guns during training activities.

For loggerhead sea turtles, the largest contributors of impacts from sonar are Acoustic and Oceanographic Research for testing activities, with more impacts during the warm season, and Vehicle Testing for testing activities, with more impacts during the warm season. The largest contributor of impacts from explosives are Mine Neutralization Explosive Ordnance Disposal for training activities with impacts during the warm season only.

Estimated behavioral and TTS impacts from sonar and explosives are expected to be short term and would not result in substantial changes to behavior, growth, survival, annual reproductive success, lifetime reproductive success, or species recruitment, for an individual and would not result in population-level impacts. Low levels of estimated AINJ from sonar and explosives, and injuries from explosives may have deleterious effects on the fitness of an individual turtle but are not expected to impact the fitness of enough individuals to cause population level effects.

Based on the analysis presented above, activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> loggerhead sea turtles in the North Pacific DPS. The use of sonars and explosives during training activities <u>may affect, and are likely to adversely affect,</u> loggerhead sea turtles in the North Pacific DPS. Activities that involve the use of pile driving are <u>not applicable</u> to loggerhead sea turtles in the North Pacific DPS because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> loggerhead sea turtles in the North Pacific DPS. The use of sonars and explosives during testing activities <u>may affect, and are likely to adversely affect,</u> loggerhead sea turtles in the North Pacific DPS. Pile diving activities are not conducted during testing.

Table 3.3-4: Estimated Effects to Loggerhead Sea turtles over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	36	60	3	(1)	0
Explosive	Navy Testing	31	82	3	1	0
Explosive	USCG Training	0	0	-	-	-
Explosive	Army Training	(1)	1	-	-	-
Sonar	Navy Training	1	(1)	-	-	-

Source	Category	BEH	TTS	AINJ	INJ	MORT
Sonar	Navy Testing	55	516	3	-	-
Maximum Annual Total		**124**	**660**	**9**	**2**	**0**

Season	Percent of Total Effects			
	SOCAL	PMSR	HRC	High Seas
Warm	56%	11%	14%	2%
Cold	0%	0%	16%	2%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Acoustic and Oceanographic Research (ONR)	Navy Testing	67%
Vehicle Testing	Navy Testing	7%
Mine Neutralization Explosive Ordnance Disposal	Navy Training	6%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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3.3.4 Olive Ridley Sea Turtle (*Lepidochelys olivacea*) – Threatened, Endangered

Olive ridley sea turtles that nest along the Pacific coast of Mexico are listed as endangered under the ESA, while all other populations are listed under the ESA as threatened. Olive ridley sea turtles do not have designated DPSs, and do not have designated critical habitat in the Study Area. Model-predicted impacts are presented in Table 3.3-5.

The olive ridley has a circumtropical distribution, occurring in the Atlantic, Pacific, and Indian Oceans (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2014). In the eastern Pacific, olive ridleys typically occur in tropical and subtropical waters, as far south as Peru and as far north as California, but occasionally have been documented as far north as Alaska. The olive ridley is mainly a pelagic sea turtle but they also inhabit coastal areas.

Olive ridley sea turtles may be exposed to sonar, air guns, vessel noise, aircraft noise, weapons noise, and explosives associated with military readiness activities throughout the year. Olive ridley sea turtles would not overlap with pile driving activities in Port Hueneme, therefore, impacts from pile driving to olive ridley sea turtles are not further analyzed. Analysis of the impacts from vessel noise, aircraft noise, and weapons noise on olive ridley sea turtles relies on the information under the respective acoustic substressor in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives).

Results from the Navy Acoustics Effects Model (Table 3.3-5) shows that olive ridley sea turtles in the Study Area may exhibit behavioral reactions, TTS, and AINJ from sonar and explosives over the course of a year. No impacts were estimated to occur from the use of air guns during training activities.

For olive ridley sea turtles, the largest contributors of impacts from sonar are due to Acoustic and Oceanographic Research for testing activities, with more impacts during the cold season, and Vehicle Testing for testing activities, with more impacts during the warm season. The largest contributor of impacts from explosives are due to Naval Surface Fire Support Exercise for training activities, with impacts occurring equally during the warm and cold seasons.

Estimated behavioral and TTS impacts from sonar and explosives are expected to be short term and would not result in substantial changes to behavior, growth, survival, annual reproductive success, lifetime reproductive success, or species recruitment, for an individual and would not result in population-level impacts. Low levels of estimated AINJ from sonar and explosives may have deleterious effects on the fitness of an individual turtle but are not expected to impact the fitness of enough individuals to cause population level effects.

Based on the analysis presented above, the use of sonars and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, olive ridley sea turtles. The use of explosives during training activities may affect, and are likely to adversely affect, olive ridley sea turtles. Activities that involve the use of pile driving are not applicable to olive ridley sea turtles because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, olive ridley sea turtles. The use of sonars and explosives during testing activities may affect, and are likely to adversely affect, olive ridley sea turtles. Pile diving activities are not conducted during testing.

Table 3.3-5: Estimated Effects to Olive Ridley Sea Turtles over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	2	5	(1)	0	-
Explosive	Navy Testing	(1)	2	(1)	-	-
Explosive	USCG Training	0	-	-	-	-
Explosive	Army Training	(1)	2	(1)	-	-
Sonar	Navy Testing	27	194	1	-	-
Maximum Annual Total		**31**	**203**	**4**	**0**	**-**

Season	Percent of Total Effects: HRC	Percent of Total Effects: High Seas
Warm	44%	5%
Cold	46%	5%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Acoustic and Oceanographic Research (ONR)	Navy Testing	83%
Vehicle Testing	Navy Testing	12%

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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3.3.5 Leatherback Sea Turtle (*Dermochlys coriacea*) - Endangered

Leatherback sea turtles are ESA-listed as endangered throughout their range with no designated DPSs. There is designated critical habitat for the leatherback sea turtle in the Study Area. Model-predicted impacts are presented in Table 3.3-6.

The leatherback sea turtle is distributed worldwide in tropical and temperate waters of the Atlantic, Pacific, and Indian Oceans. Pacific leatherbacks are split into western and eastern Pacific subpopulations based on their distribution and biological and genetic characteristics. Only western Pacific leatherbacks are expected to be found within the Study Area (National Marine Fisheries Service, 2018b). The leatherback sea turtle occurs in offshore areas surrounding the Hawaiian Islands beyond the 100 m isobath and rarely occur inshore of this isobath. Leatherback sea turtles are regularly seen off the western coast of the United States, with the greatest densities found in waters off central California where sea surface temperatures are highest during the summer and fall. These warmer temperatures and other oceanographic conditions create favorable habitat for leatherback sea turtle prey.

Leatherback sea turtles may be exposed to sonar, air guns, vessel noise, aircraft noise, weapons noise, and explosives associated with military readiness activities throughout the year. Leatherback sea turtles would not overlap with pile driving activities in Port Hueneme, therefore, impacts from pile driving to leatherback sea turtles are not further analyzed. Analysis of the impacts from vessel noise, aircraft noise, and weapons noise on green turtles relies on the information under the respective acoustic substressor in Section 3.1 (Impacts Due to Each Acoustic Substressor and Explosives).

Results from the Navy Acoustics Effects Model (Table 3.3-6) shows that leatherback sea turtles in the Study Area may exhibit behavioral reactions, TTS, and AINJ from sonar and explosives over the course of a year. No impacts were estimated to occur from the use of air guns during training activities.

For leatherback sea turtles, the largest contributor of impacts from sonar are due to Acoustic and Oceanographic Research for testing activities, with more impacts during the cold season. The largest contributor of impacts from explosives are due to Small Ship Shock Trial for testing activities, with impacts during the cold season only. The largest contributor of impacts in designated critical habitat is from the use of sonar during Acoustic and Oceanographic Research for testing activities during the cold season.

Estimated behavioral and TTS impacts from sonar and explosives are expected to be short term and would not result in substantial changes to behavior, growth, survival, annual reproductive success, lifetime reproductive success, or species recruitment, for an individual and would not result in population-level impacts. Low levels of estimated AINJ from sonar and explosives may have deleterious effects on the fitness of an individual turtle but are not expected to impact the fitness of enough individuals to cause population level effects.

Based on the analysis presented above, the use of sonars and activities that produce vessel, aircraft, and weapons noise during training activities <u>may affect, but are not likely to adversely affect,</u> leatherback sea turtles. The use of explosives during training activities <u>may affect, and are likely to adversely affect,</u> leatherback sea turtles. Activities that involve the use of pile driving are <u>not applicable</u> to leatherback sea turtles because there is no geographic overlap of this stressor with species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of air guns and activities that produce vessel, aircraft, and weapons noise during testing activities <u>may affect, but are not likely to adversely affect,</u> leatherback sea turtles. The use of sonars and explosives during testing activities <u>may affect, and are likely to adversely affect,</u> leatherback sea turtles. Pile diving activities are not conducted during testing.

<u>*Critical Habitat*</u>

Critical habitat designated for the leatherback sea turtle includes approximately 16,910 square miles (43,798 square km) along the California coast from Point Arena to Point Arguello east of the 3,000-meter depth contour; and 25,004 square miles (64,760 square km) from Cape Flattery, Washington to Cape Blanco, Oregon east of the 2,000-meter depth contour. The designated areas comprise approximately 41,914 square miles (108,558 square km) of marine habitat and include waters from the ocean surface down to a maximum depth of 262 feet (80 m) (National Marine Fisheries Service, 2012). The physical and biological features essential for the conservation of leatherback sea turtles in marine waters off the U.S. West Coast is the occurrence of prey species, primarily *scyphomedusae* of the order *Semaeostomeae* (e.g., *Chrysaora*, *Aurelia*, *Phacellophora*, and *Cyanea*), of sufficient condition, distribution, diversity, abundance, and density necessary to support individual as well as population growth, reproduction, and development of leatherback sea turtles. This critical habitat designation overlaps with the California portion of the Study Area and noise from sonars, air guns, explosives and vessels, aircraft, and weapons firing. Pile driving activities in Port Hueneme do not overlap with critical habitat designated for the leatherback sea turtle in the California portion of the Study Area. Although use of explosives could kill individuals of identified prey species, these impacts would be localized and infrequent. Noise due to other acoustic stressors would not affect prey condition, distribution, diversity, abundance, or density.

The use of sonars and explosives, and activities that produce vessel, aircraft, and weapons noise during training activities may affect, but are not likely to adversely affect, designated critical habitat for leatherback sea turtles. Activities that involve the use of pile driving are not applicable to leatherback sea turtle critical habitats because there is no geographic overlap of this stressor with those critical habitats. Air gun activities are not conducted during training.

The use of sonars, air guns, and explosives, and activities that produce vessel, aircraft, and weapons noise during testing activities may affect, but are not likely to adversely affect, designated critical habitat for leatherback sea turtles. Pile diving activities are not conducted during testing.

Table 3.3-6: Estimated Effects to Leatherback Sea turtles over a Maximum Year of Proposed Activities

Source	Category	BEH	TTS	AINJ	INJ	MORT
Explosive	Navy Training	3	2	(1)	-	-
Explosive	Navy Testing	2	5	(1)	0	-
Explosive	Army Training	(1)	(1)	(1)	0	-
Sonar	Navy Training	0	0	-	-	-
Sonar	Navy Testing	39	334	2	-	-
Maximum Annual Total		**45**	**342**	**5**	**0**	**-**

Season	Percent of Total Effects			
	SOCAL	NOCAL	HRC	High Seas
Warm	13%	14%	15%	4%
Cold	17%	16%	17%	4%

Activities Causing 5 Percent or More of Total Effects	Category	Percent of Total Effects
Acoustic and Oceanographic Research (ONR)	Navy Testing	87%
Vehicle Testing	Navy Testing	10%

Area Type	Area Name (Active Months)	BEH	TTS	AINJ	INJ	MORT
Critical Habitat	CA Coastal Marine Waters (All)	0	16	0	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
For BEH, TTS, AINJ, INJ, MORT annual effects: Dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Asterisk (*) indicates no reliable abundance estimate is available.
See beginning of Section 2.4 for full explanation of table sections.
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3.3.6 Impact Summary Tables

The tables in in this section show impacts on all species for the following:

- Maximum annual and seven-year total impacts due to sonar use during Navy training activities and during Navy testing activities. Stocks for which no take is requested are not shown. The maximum annual impacts per species are the same values presented in each species impact assessment above. See Table 3.3-7 through Table 3.3-10.
- Maximum annual and seven-year total impacts due to air gun use during Navy testing activities. Stocks for which no take is requested are not shown. Note that no air gun use is proposed during training activities. See Table 3.3-11 and Table 3.3-12.

- Maximum annual and seven-year total impacts due to explosives during Navy training activities, during Navy testing activities (including Ship Shock Trials), during Coast Guard training activities, and during Army training activities. Stocks for which no take is requested are not shown. Consistent with previous analyses, the impacts due to a maximum year of Ship Shock Trials (one event) are also shown separately. See Table 3.3-13 through Table 3.3-20.
- Maximum annual and seven-year total impacts due to Small Ship Shock Trials, part of Navy testing. Stocks for which no take is requested are not shown. Note that these results are included in the overall explosive results but broken out in these tables for clarity. See Table 3.3-21.

The seven-year impacts are created by summing seven years of impacts considering any variation in the annual levels of activities and including any fractional values. The final summed seven-year value is then rounded following standard rounding rules. That is, the seven-year impacts are not the result of summing the rounded annual results. If a seven-year sum was larger than multiplying the rounded maximum annual value by seven, the Navy increased the annual maximum value above the value predicted by the model results. This was done by dividing the seven-year sum of impacts by seven then rounding up, rather than following standard rounding rules, to estimate the annual impacts. For example, this could happen if maximum annual results are 1.34 (rounds to 1 annually) and seven-year results are 8.60 (rounds to 9), where 9 over seven years is greater than seven times 1. In this instance, the maximum annual impacts would be adjusted from one to two based on rounding up the quotient of dividing the seven-year impacts by seven. In no cases does implementing this approach result in reducing the impacts predicted by the Navy's Acoustic Effects Model.

3.3.6.1 Sonar Impact Summary Tables

Table 3.3-7: Estimated Effects to Sea Turtles from Sonar and Other Active Transducers Over One Year of Maximum Navy Training

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Leatherback sea turtle	Primary	0	0	-
Loggerhead sea turtle	North Pacific DPS	1	(1)	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-8 Estimated Effects to Sea Turtles from Sonar and Other Active Transducers Over Seven Years of Navy Training

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Leatherback sea turtle	Primary	0	0	-
Loggerhead sea turtle	North Pacific DPS	5	1	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-9: Estimated Effects to Sea Turtles from Sonar and Other Active Transducers Over One Year of Maximum Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Green sea turtle	East Pacific DPS	29	552	7
	Central North Pacific DPS	15	45	0
Hawksbill sea turtle	Primary	1	6	0
Leatherback sea turtle	Primary	39	334	2
Loggerhead sea turtle	North Pacific DPS	55	516	3
Olive ridley sea turtle	Primary	27	194	1

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-10: Estimated Effects to Sea Turtles from Sonar and Other Active Transducers Over Seven Years of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Green sea turtle	East Pacific DPS	202	3,419	44
	Central North Pacific DPS	96	278	0
Hawksbill sea turtle	Primary	3	35	0
Leatherback sea turtle	Primary	190	2,069	14
Loggerhead sea turtle	North Pacific DPS	321	3,204	18
Olive ridley sea turtle	Primary	134	1,202	7

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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3.3.6.2 Air Gun Impact Summary Tables

Table 3.3-11: Estimated Effects to Sea Turtles from Air Guns Over One Year of Maximum Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Green sea turtle	East Pacific DPS	-	(1)	-
	Central North Pacific DPS	-	(1)	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-12: Estimated Effects to Sea Turtles from Air Guns Over Seven Years of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ
ESA-Listed				
Green sea turtle	East Pacific DPS	-	2	-
	Central North Pacific DPS	-	1	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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3.3.6.3 Explosives Impact Summary Tables

Table 3.3-13: Estimated Effects to Sea Turtles from Explosives Over One Year of Maximum Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	East Pacific DPS	9	8	1	1	0
	Central North Pacific DPS	2,019	1,061	41	2	1
Hawksbill sea turtle	Primary	18	10	(1)	-	-
Leatherback sea turtle	Primary	3	2	(1)	-	-
Loggerhead sea turtle	North Pacific DPS	36	60	3	1	0
Olive ridley sea turtle	Primary	2	5	(1)	0	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-14: Estimated Effects to Sea Turtles from Explosives Over Seven Years of Navy Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	East Pacific DPS	61	51	4	1	0
	Central North Pacific DPS	14,059	7,334	284	10	5
Hawksbill sea turtle	Primary	122	70	2	-	-
Leatherback sea turtle	Primary	19	10	1	-	-
Loggerhead sea turtle	North Pacific DPS	234	397	17	2	0
Olive ridley sea turtle	Primary	13	29	1	0	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 3.3-15: Estimated Effects to Sea Turtles from Explosives Over One Year of Maximum Navy Testing

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	East Pacific DPS	2	7	1	0	0
	Central North Pacific DPS	32	58	4	1	0
Hawksbill sea turtle	Primary	0	1	0	-	-
Leatherback sea turtle	Primary	2	5	(1)	0	-

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
Loggerhead sea turtle	North Pacific DPS	31	82	3	1	0
Olive ridley sea turtle	Primary	(1)	2	(1)	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-16: Estimated Effects to Sea Turtles from Explosives Over Seven Years of Navy Testing

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	East Pacific DPS	12	33	6	0	0
	Central North Pacific DPS	222	321	19	1	0
Hawksbill sea turtle	Primary	0	3	0	-	-
Leatherback sea turtle	Primary	10	15	2	0	-
Loggerhead sea turtle	North Pacific DPS	207	300	14	5	0
Olive ridley sea turtle	Primary	2	9	2	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-17: Estimated Effects to Sea Turtles from Explosives Over One Year of Maximum Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Loggerhead sea turtle	North Pacific DPS	0	0	-	-	-
Olive ridley sea turtle	Primary	0	-	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-18: Estimated Effects to Sea Turtles from Explosives Over Seven Years of Coast Guard Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Loggerhead sea turtle	North Pacific DPS	0	0	-	-	-
Olive ridley sea turtle	Primary	0	-	-	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
version.20241108

Table 3.3-19: Estimated Effects to Sea Turtles from Explosives Over One Year of Maximum Army Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	Central North Pacific DPS	(1)	(1)	-	-	-
Hawksbill sea turtle	Primary	-	(1)	-	-	-
Leatherback sea turtle	Primary	(1)	(1)	(1)	0	-
Loggerhead sea turtle	North Pacific DPS	(1)	1	-	-	-
Olive ridley sea turtle	Primary	(1)	2	(1)	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Values in parentheses are rounded up from less than 0.5 based on the 7-year rounding rules discussed in Section 2.4.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-20: Estimated Effects to Sea Turtles from Explosives Over Seven Years of Army Training

Species	Stock or Population	BEH	TTS	AINJ	INJ	MORT
ESA-Listed						
Green sea turtle	Central North Pacific DPS	2	1	-	-	-
Hawksbill sea turtle	Primary	-	1	-	-	-
Leatherback sea turtle	Primary	1	2	1	0	-
Loggerhead sea turtle	North Pacific DPS	2	6	-	-	-
Olive ridley sea turtle	Primary	1	12	2	-	-

BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
Nsd = No stock designation under MMPA.
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Table 3.3-21: Estimated Effects to Sea Turtles from Small Ship Shock Trials over a Maximum Year of Navy Testing (1 Event)

Species	Stock	TTS	AINJ	INJ	MORT
ESA-Listed					
Green sea turtle	East Pacific DPS	2	-	-	-
Leatherback sea turtle	Primary	3	-	-	-
Loggerhead sea turtle	North Pacific DPS	42	1	0	0

TTS = Temporary Threshold Shift, AINJ = Auditory Injury, INJ = Non-Auditory Injury, MORT = Mortality
A dash (-) indicates a (true zero), and zero (0) indicates a rounded value less than 0.5.
Stocks are not shown if no effects are estimated.
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3.4 Range to Effects

The following section provides the range (distance) over which specific physiological or behavioral effects are expected to occur based on the acoustic and explosive criteria in the *Criteria and Thresholds TR*, and the acoustic and explosive propagation calculations from the Navy Acoustic Effects Model described in the *Quantitative Analysis TR*. The ranges to effects are shown for representative sonar systems, air guns, and explosive bins from E1 (0.1–0.25 lb. NEW) to E16 (>7,500–14,500 lb. NEW). Ranges are determined by modeling the distance that noise from a source will need to propagate to reach exposure level thresholds specific to a hearing group that will cause behavioral response, TTS, AINJ, non-auditory injury, and mortality. Ranges to effects were calculated for sea turtle species only and are utilized to help predict impacts from acoustic and explosive sources and assess the benefit of mitigation zones.

Tables present median and standard deviation ranges to effects for each hearing group, source or bin, bathymetric depth intervals of ≤200 m and >200 m to represent areas on an off the continental shelf, exposure duration (sonar), and representative cluster size (air guns and explosives). Ranges to effects consider propagation effects of sources modeled at different locations (i.e., analysis points), seasons, source depths, and radials (i.e., each analysis point considers propagation effects in different x-y directions by modeling 18 radials in azimuthal increments of 20° to obtain 360° coverage around an analysis point).

Boxplots visually present the distribution, variance, and outlier ranges for a given combination of a source or bin, hearing group, and effect. On the boxplots, outliers are plotted as dots, the lowest and highest non-outlier ranges are the extent of the left and right horizontal lines respectively that extend from the sides of a colored box, and the 25th, 50th (i.e., median), and 75th percentiles are the left edge, center line, and right edge of a colored box respectively.

3.4.1 Range to Effects for Sonars and Other Transducers

The six representative sonar systems with ranges to effects are not applicable to reptiles since they produce sound at frequencies greater than the upper hearing range of reptiles (i.e., > 2 kHz).

3.4.2 Range to Effects for Air Guns

Ranges to effects for air guns were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a hearing group that would cause behavioral response, TTS, and AINJ, as described in the *Criteria and Thresholds TR*. The air gun ranges to effects for TTS and AINJ that are in the tables are based on the metric (i.e., SEL or SPL) that produced longer ranges.

Table 3.4-1: Sea Turtle Ranges to Effects for Air Guns

Bin	Depth	Cluster Size	BEH	TTS	AINJ
Air Gun	≤200 m	1	NA	2 m (0 m)	1 m (0 m)
		10	20 m (1 m)	60 m (3 m)	11 m (0 m)
	>200 m	1	NA	2 m (0 m)	1 m (0 m)
		10	20 m (1 m)	60 m (3 m)	11 m (0 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
Table Created: 05 Aug 2024 4:03:02 PM

3.4.3 Range to Effects for Pile Driving

Pile driving activities in Port Hueneme are not applicable to reptiles due to a lack of geographic overlap.

3.4.4 Range to Effects for Explosives

Ranges to effects for explosives were determined by modeling the distance that noise from an explosion would need to propagate to reach exposure level thresholds specific to a hearing group that would cause behavioral response, TTS, AINJ, non-auditory injury, and mortality, as described in the *Criteria and Thresholds TR*.

The Navy Acoustic Effects Model cannot account for the highly non-linear effects of cavitation and surface blow off for shallow underwater explosions, nor can it estimate the explosive energy entering the water from a low-altitude detonation. Thus, for this analysis, in-air sources detonating at or near (within 10 m) the surface are modeled as if detonating completely underwater at a source depth of 0.1 m, with all energy reflected into the water rather than released into the air. Therefore, the amount of explosive and acoustic energy entering the water, and consequently the estimated ranges to effects, are likely to be overestimated. In the tables below, near surface explosions can occur for bathymetric depth intervals of ≤200 m and >200 m.

The tables below provide the ranges for a representative cluster size for each bin. Ranges for behavioral response are only provided if more than one explosive cluster occurs. Single explosions at received sound levels below TTS and AINJ thresholds are most likely to result in a brief alerting or orienting response. Due to the lack of subsequent explosions, a significant behavioral response is not expected for a single explosive cluster. For events with multiple explosions, sound from successive explosions can be expected to accumulate and increase the range to the onset of an impact based on SEL thresholds. Modeled ranges to TTS and AINJ based on peak pressure for a single explosion generally exceed the modeled ranges based on SEL even when accumulated for multiple explosions. Peak pressure-based ranges are estimated using the best available science; however, data on peak pressure at far distances from explosions are very limited. The explosive ranges to effects for TTS and AINJ that are in the tables are based on the metric (i.e., SEL or SPL) that produced longer ranges.

For non-auditory injury in the tables, the larger of the range to slight lung injury or gastrointestinal tract injury was used as a conservative estimate, and the boxplots present ranges for both metrics for comparison. Animals within water volumes encompassing the estimated range to non-auditory injury would be expected to receive minor injuries at the outer ranges, increasing to more substantial injuries, and finally mortality as an animal approaches the detonation point.

Table 3.4-2: Sea Turtle Ranges to Effects for Explosives

Bin	Depth	Cluster Size	BEH	TTS	AINJ
E1	≤200 m	1	NA	71 m (2 m)	43 m (4 m)
		5	100 m (153 m)	71 m (2 m)	43 m (4 m)
		25	324 m (319 m)	134 m (208 m)	43 m (4 m)
		50	247 m (142 m)	141 m (96 m)	43 m (4 m)
	>200 m	1	NA	71 m (2 m)	43 m (4 m)
		5	90 m (81 m)	71 m (2 m)	43 m (4 m)
		25	230 m (178 m)	90 m (103 m)	43 m (4 m)
		50	440 m (223 m)	270 m (148 m)	43 m (4 m)
E2	≤200 m	1	NA	100 m (11 m)	56 m (7 m)
	>200 m	1	NA	101 m (11 m)	57 m (7 m)
E3	≤200 m	1	NA	156 m (17 m)	82 m (9 m)
		5	542 m (433 m)	286 m (298 m)	82 m (9 m)

Bin	Depth	Cluster Size	BEH	TTS	AINJ
		25	1,044 m (523 m)	656 m (379 m)	82 m (9 m)
	>200 m	1	NA	270 m (118 m)	81 m (8 m)
		5	520 m (268 m)	270 m (175 m)	81 m (8 m)
		25	432 m (126 m)	270 m (79 m)	81 m (8 m)
E4	≤200 m	1	NA	757 m (331 m)	127 m (14 m)
	>200 m	1	NA	433 m (64 m)	123 m (15 m)
E5	≤200 m	1	NA	249 m (37 m)	130 m (19 m)
		5	901 m (444 m)	465 m (273 m)	130 m (19 m)
	>200 m	1	NA	250 m (172 m)	126 m (18 m)
		5	929 m (557 m)	550 m (327 m)	126 m (18 m)
		20	2,500 m (635 m)	1,583 m (490 m)	320 m (145 m)
E6	≤200 m	1	NA	1,207 m (815 m)	210 m (206 m)
		15	4,133 m (1,046 m)	3,232 m (643 m)	996 m (118 m)
	>200 m	1	NA	632 m (296 m)	209 m (21 m)
E7	≤200 m	1	NA	601 m (323 m)	179 m (30 m)
	>200 m	1	NA	949 m (483 m)	176 m (34 m)
E8	≤200 m	1	NA	1,186 m (137 m)	314 m (67 m)
	>200 m	1	NA	1,191 m (154 m)	308 m (66 m)
E9	≤200 m	1	NA	1,683 m (843 m)	345 m (322 m)
	>200 m	1	NA	1,500 m (827 m)	342 m (51 m)
E10	≤200 m	1	NA	2,276 m (445 m)	511 m (126 m)
	>200 m	1	NA	2,243 m (445 m)	499 m (117 m)
E11	≤200 m	1	NA	4,528 m (1,177 m)	957 m (106 m)
	>200 m	1	NA	4,472 m (1,363 m)	915 m (117 m)
E12	≤200 m	1	NA	2,758 m (452 m)	583 m (91 m)
	>200 m	1	NA	2,396 m (355 m)	604 m (96 m)

Median ranges with standard deviation ranges in parentheses, TTS and AINJ = the greater of respective SPL and SEL ranges, behavioral response criteria are applied to explosive clusters >1
BEH = Significant Behavioral Response, TTS = Temporary Threshold Shift, AINJ = Auditory Injury, NA = not applicable
Table Created: 05 Aug 2024 4:43:39 PM

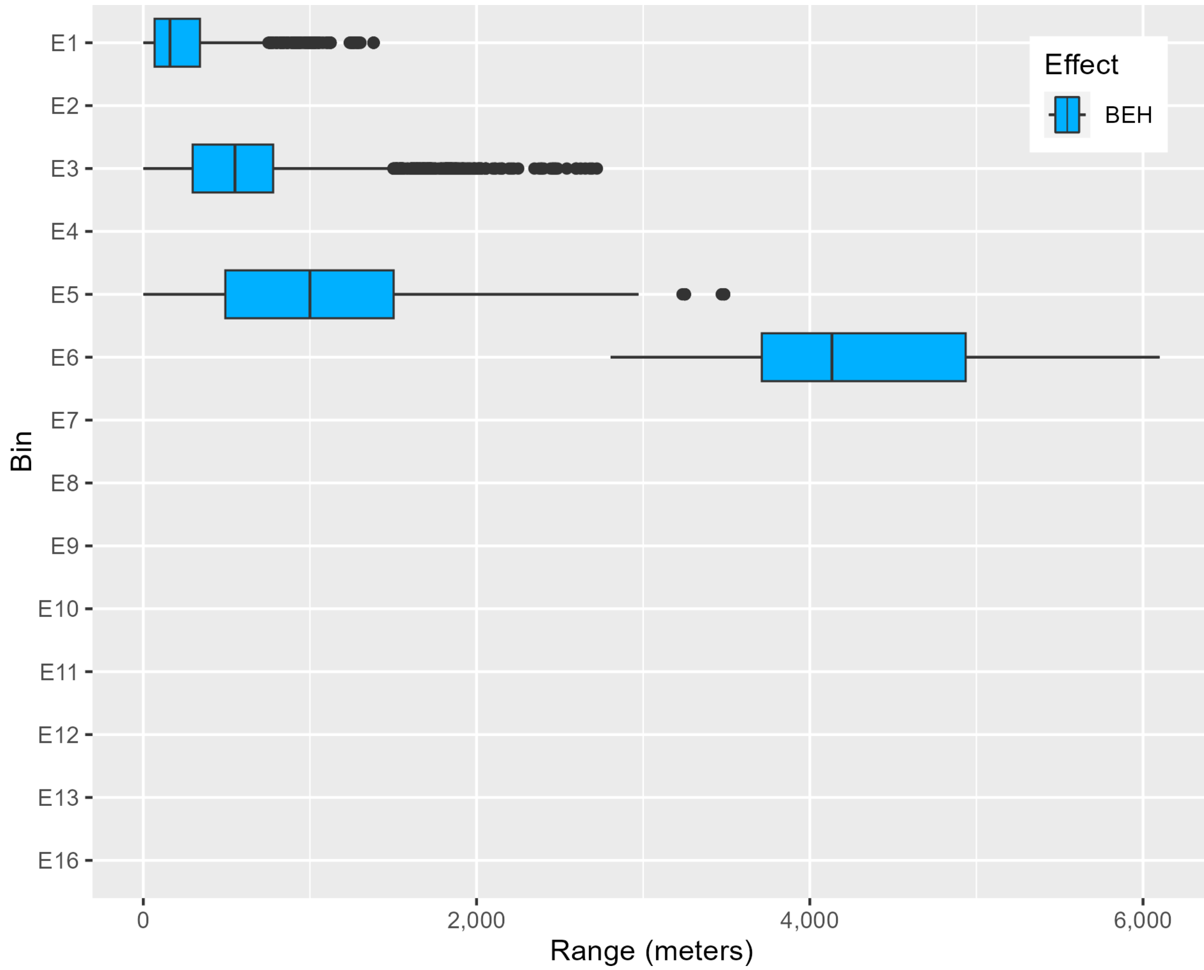

Figure 3.4-1: Sea Turtle Ranges to Behavioral Response for Explosives

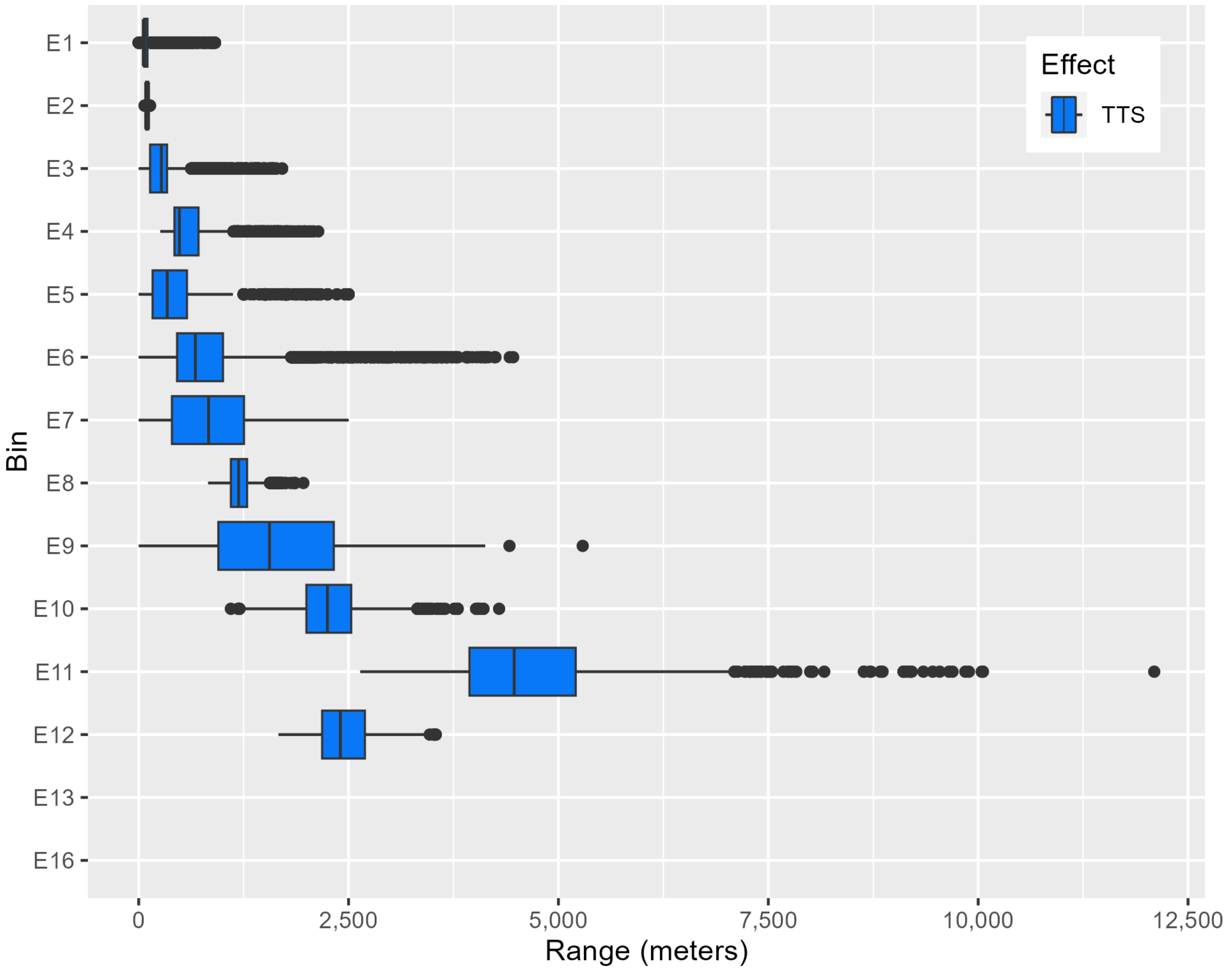

Figure 3.4-2: Sea Turtle Ranges to Temporary Threshold Shift for Explosives

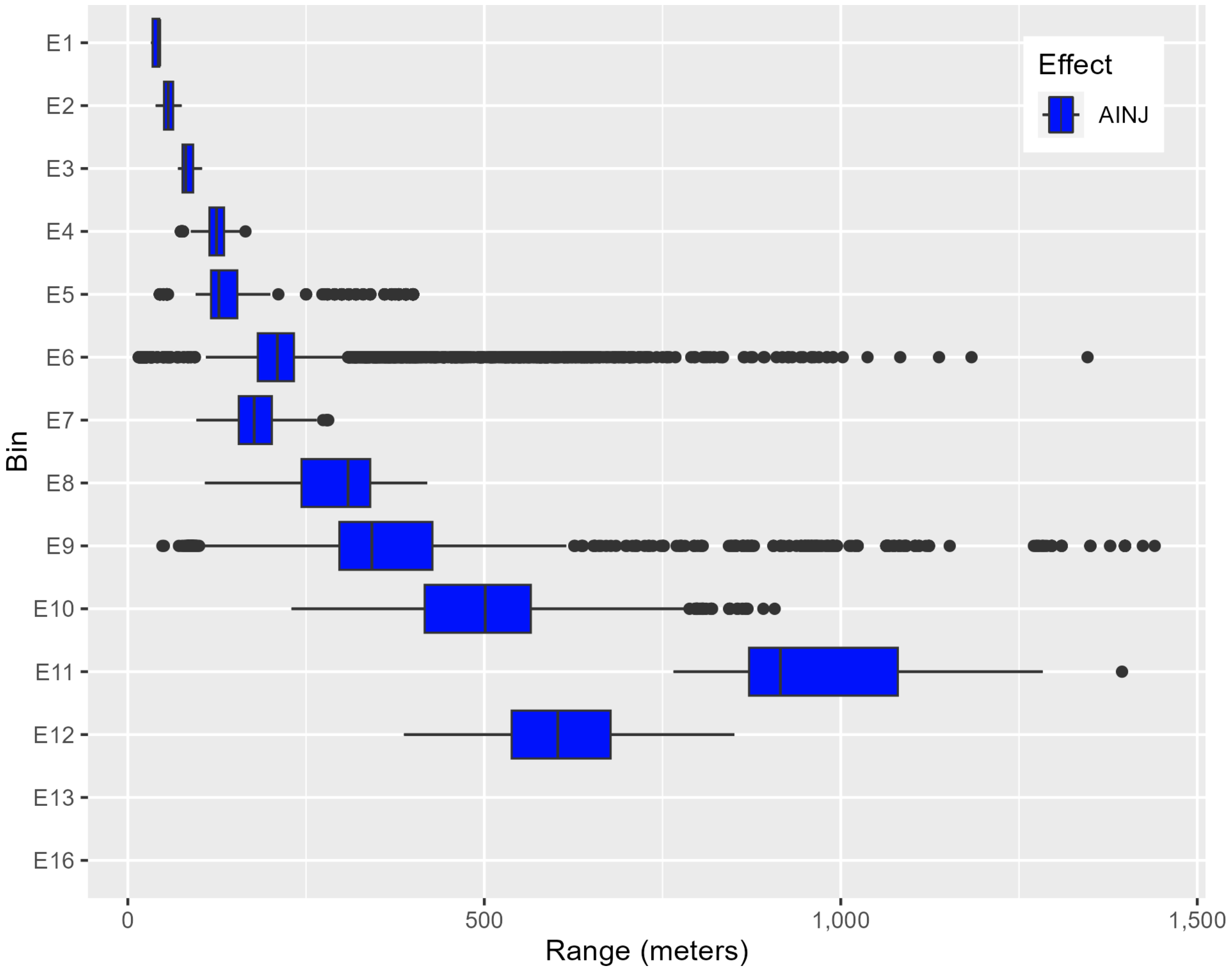

Figure 3.4-3: Sea Turtle Ranges to Auditory Injury for Explosives

Table 3.4-3: Explosive Ranges to Injury and Mortality for Sea Turtles as a Function of Animal Mass

Bin	Effect	10 kg	250 kg	1,000 kg
E1	INJ	22 m (0 m)	22 m (1 m)	21 m (0 m)
	MORT	3 m (0 m)	1 m (0 m)	0 m (0 m)
E2	INJ	28 m (2 m)	27 m (2 m)	26 m (1 m)
	MORT	6 m (1 m)	2 m (1 m)	1 m (0 m)
E3	INJ	33 m (5 m)	34 m (7 m)	42 m (2 m)
	MORT	7 m (1 m)	4 m (1 m)	2 m (0 m)
E4	INJ	52 m (6 m)	53 m (6 m)	57 m (4 m)
	MORT	11 m (3 m)	4 m (3 m)	2 m (1 m)
E5	INJ	69 m (2 m)	68 m (3 m)	65 m (2 m)
	MORT	15 m (2 m)	8 m (1 m)	4 m (0 m)
E6	INJ	98 m (9 m)	98 m (8 m)	97 m (7 m)
	MORT	38 m (7 m)	19 m (4 m)	12 m (1 m)
E7	INJ	90 m (15 m)	86 m (17 m)	108 m (13 m)
	MORT	18 m (2 m)	10 m (2 m)	7 m (1 m)
E8	INJ	208 m (13 m)	144 m (13 m)	166 m (3 m)
	MORT	58 m (9 m)	31 m (7 m)	18 m (2 m)
E9	INJ	334 m (38 m)	173 m (24 m)	212 m (9 m)
	MORT	147 m (19 m)	22 m (9 m)	13 m (2 m)
E10	INJ	480 m (71 m)	228 m (64 m)	266 m (19 m)
	MORT	244 m (31 m)	57 m (22 m)	16 m (6 m)
E11	INJ	586 m (30 m)	351 m (31 m)	396 m (33 m)
	MORT	323 m (9 m)	177 m (22 m)	109 m (1 m)
E12	INJ	640 m (73 m)	318 m (131 m)	352 m (2 m)
	MORT	344 m (36 m)	132 m (59 m)	20 m (2 m)

Median ranges with standard deviation ranges in parentheses, INJ = the greater of respective ranges for 1% chance of gastro-intestinal tract injury and 1% chance of injury
Table Created: 05 Aug 2024 4:43:44 PM

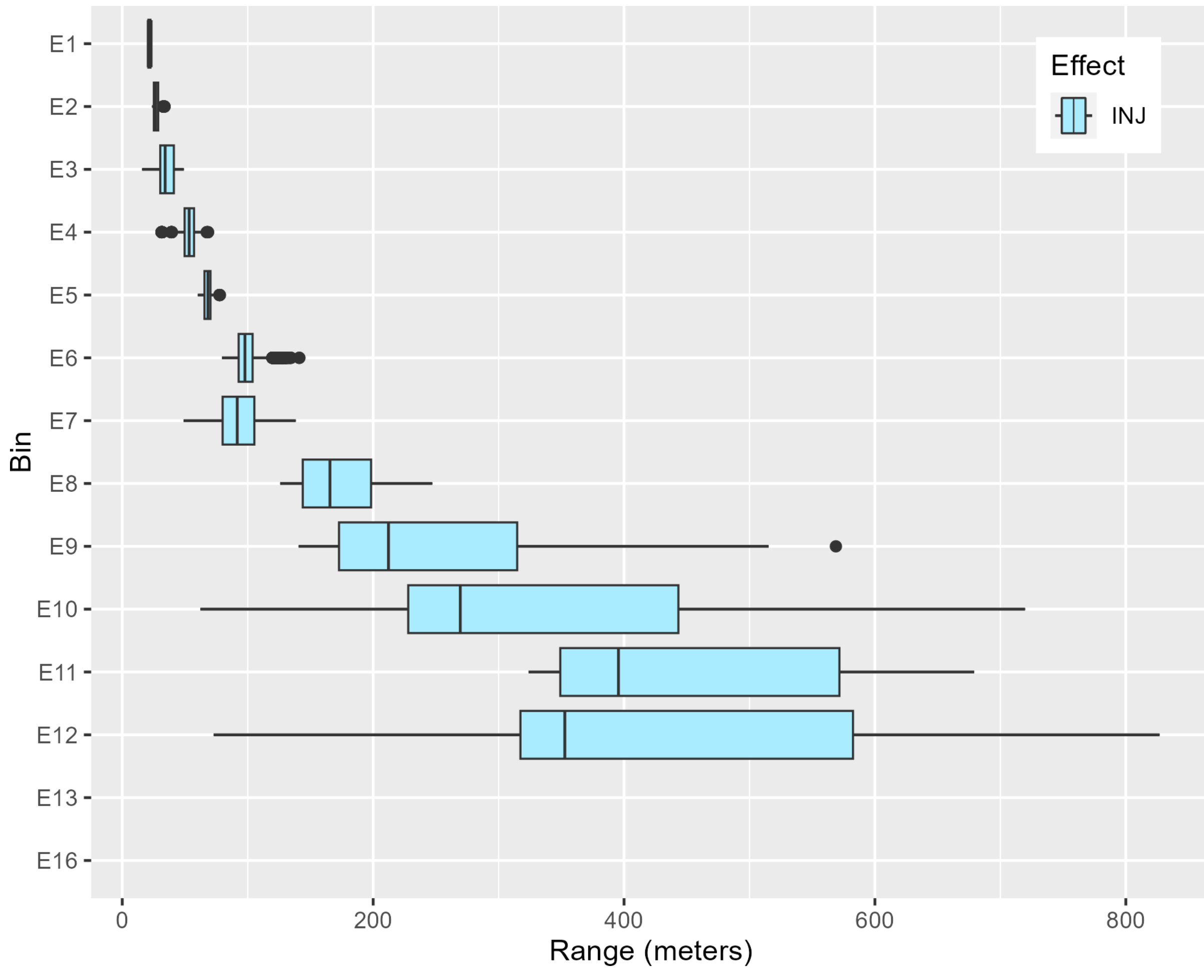

Figure 3.4-4: Explosive Ranges to Injury for Sea Turtles

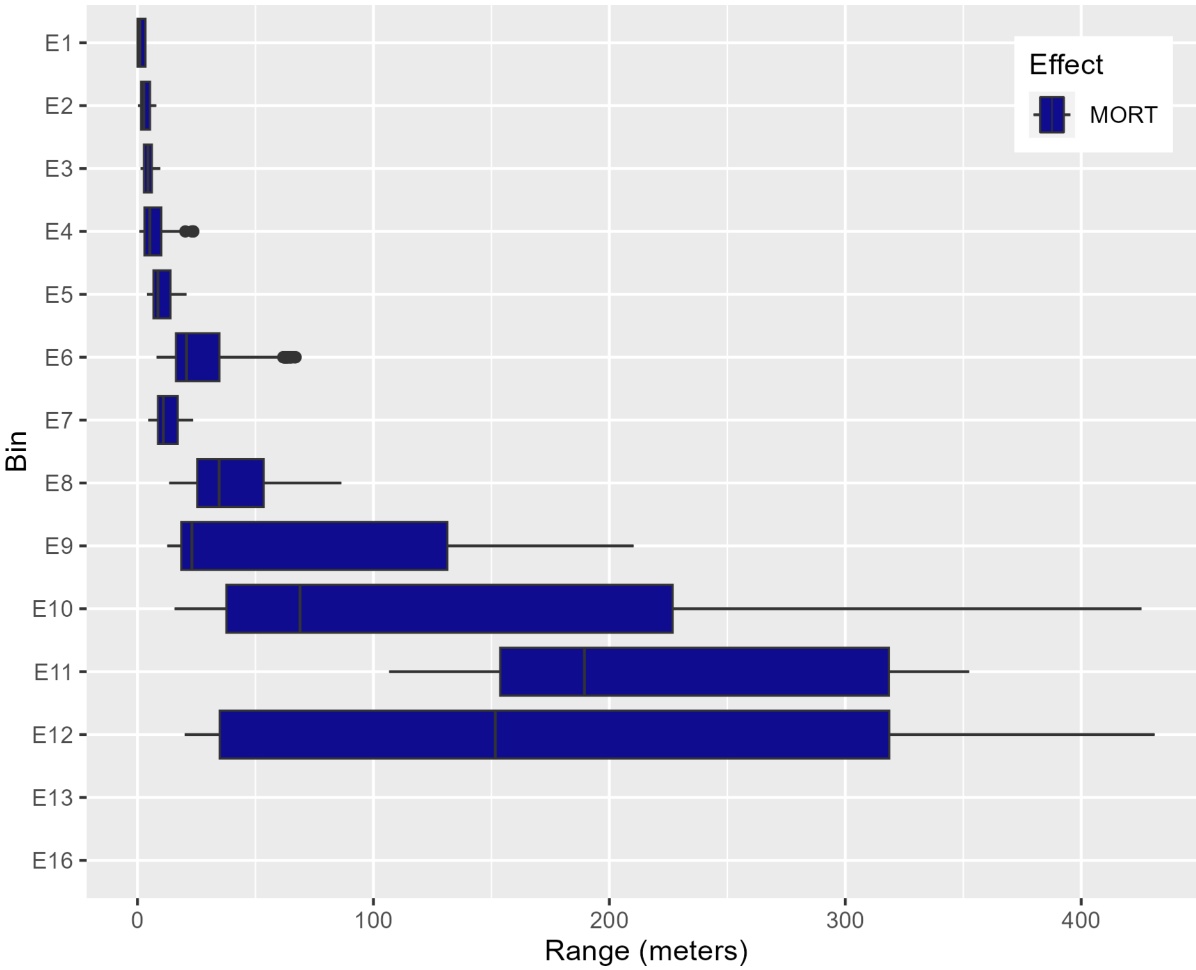

Figure 3.4-5: Explosive Ranges to Mortality for Sea Turtles

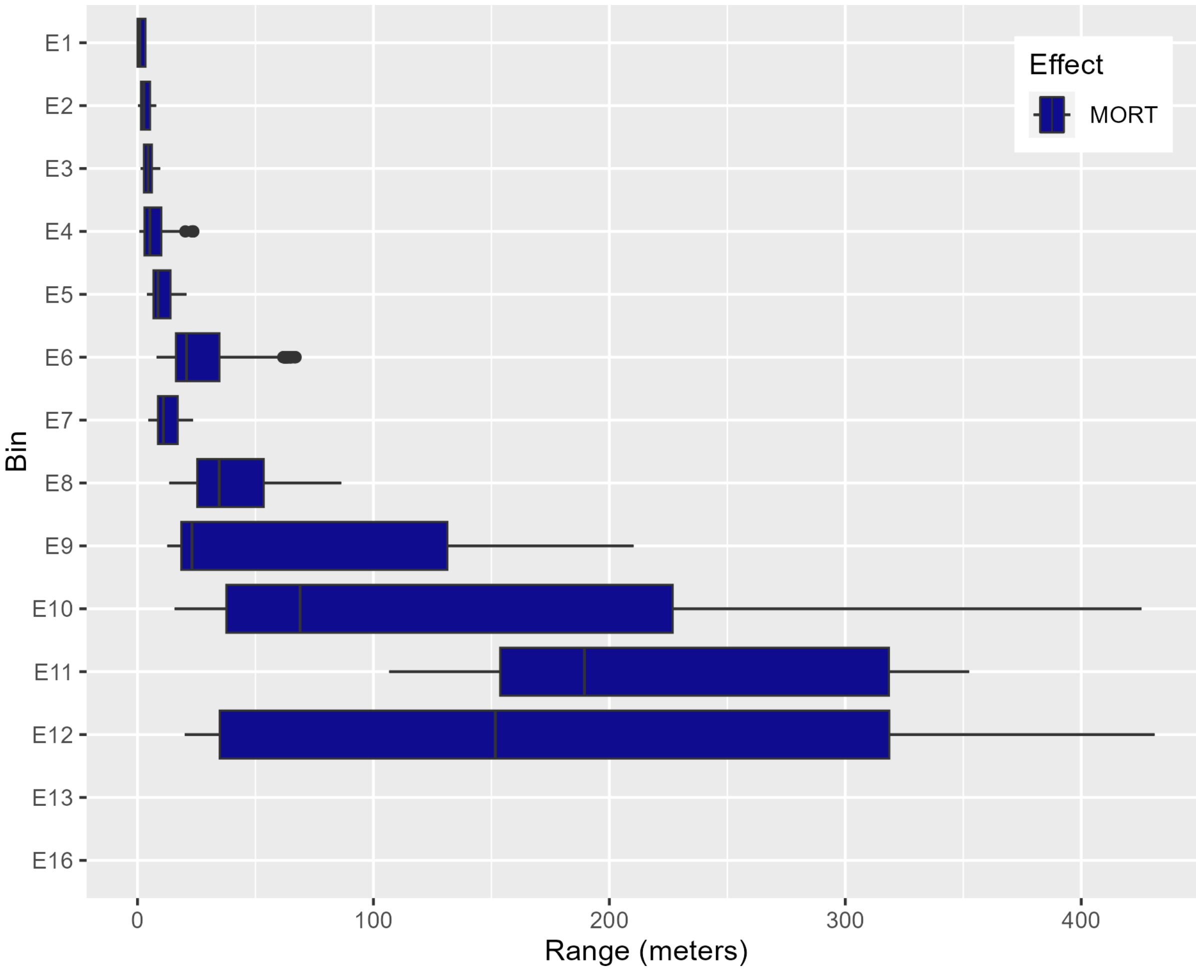

Figure 3.4-5: Explosive Ranges to Mortality for Sea Turtles

4 IMPACTS ON FISHES FROM ACOUSTIC AND EXPLOSIVE STRESSORS

This analysis is presented as follows:

- The approach to modeling and quantifying impacts, as it applies to fishes, is summarized in Section 4.1 (Quantifying Impacts on Fishes from Acoustic and Explosive Stressors).
- The impacts on fish populations that would be expected due to each type of acoustic substressor and explosives used in the Proposed Action are described in Section 4.2 (Impacts Due to each Acoustic Substressor and Explosives).
- Impacts on ESA-species (Distinct Population Segments [DPS] and Evolutionarily Significant Units [ESU]) in the Study Area, including predicted instances of harm or harassment, are presented in Section 4.3 (ESA-Listed Species Impact Assessment).

4.1 QUANTIFYING IMPACTS ON FISHES FROM ACOUSTIC AND EXPLOSIVE STRESSORS

Although the impact analysis presented below is largely qualitative, a quantitative analysis was performed to estimate ranges to effects for fishes exposed to activities that involve the use of some acoustic substressors (sonar, pile driving, and air guns) and explosives (see Section 4.4, Range to Effects, for details). As such, this section is organized differently than the preceding analyses for marine mammals and reptiles because the quantitative aspects of the analysis are included in Section 4.2 (Impacts Due to Each Acoustic Substressor and Explosives) when considering impacts on fish populations, not just ESA-species (as analyzed in Section 4.3, ESA-Listed Species Impact Assessments).

Ranges for sonar, air guns, and explosives were estimated using fish sound exposure criteria and thresholds (described below in Sections 4.1.1 through 4.4.4) and sound propagation modeling performed in the Navy's Acoustic Effects Model. Ranges to effects for pile driving (Section 4.1.3) also use the criteria described below but were modeled outside of the Navy's Acoustic Effects Model (see the *Quantitative Analysis TR* for details). Note, although ranges to effects are estimated for some stressors, density data for fishes throughout the Study Area are not available; therefore, it is not possible to estimate the total number of individuals that may be affected by Navy acoustic and explosive stressors.

Sound exposure criteria for the current analysis are largely consistent with thresholds used during previous assessments of impacts due to military readiness activities in the Study Area, with new data and modifications from previous phases described in detail below (i.e., explosive injury criteria). The literature used to derive proposed criteria and thresholds are summarized in the *Fishes Acoustic Background* section. The data presented herein represent current best available science.

4.1.1 QUANTIFYING HEARING IMPACTS FROM SONARS

Most of the available research on the effects of non-impulsive sound sources on fishes utilize tonal or broadband signals (e.g., white noise). However, experiments that utilize these types of sound sources are often not analogous to potential exposures to Navy sonars due to differences in the test stimuli and environment (i.e., tanks or aquariums). Additionally, the overall exposure durations often exceed many hours or even days, time frames that are much longer than the likely exposures fish may experience due to transiting Naval vessels that operate sonar and other transducers. The only three studies that have documented potential threshold shifts in fishes exposed to actual Naval sonar are summarized in Table

4.1-1. This data was used to derive interim sound exposure criteria consistent with proposed thresholds in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014).

Table 4.1-1: TTS Data for Fishes Exposed to Sonar

Reference	Reported SPL (dB RMS)	Exposure Duration (seconds)	Calculated cSEL [1]	Species	TTS (Y/N)
Mid-Frequency Sonar					
Halvorsen et al. (2012c)	210	15	222	Channel catfish (*Ictalurus punctatus*)[2]	Y
	210	15	222	Rainbow trout (*Oncorhynchus mykiss*)	N
Low-Frequency Sonar					
Popper et al. (2007)	193	324	218	Rainbow trout (*Oncorhynchus mykiss*)	Y
	193	648	221	Rainbow trout (*Oncorhynchus mykiss*)	Y
Halvorsen et al. (2013)	195	324	220	Channel catfish (*Ictalurus punctatus*)[2]	Y
				Largemouth bass (*Micropterus salmoides*)	N
				Yellow perch (*Perca flavescens*)	N

Notes: SPL = sound pressure level; dB RMS = decibel root mean square; cSEL = cumulative sound exposure level; TTS = temporary threshold shift. Significance is defined and reported in each publication as a statistically significant threshold shift compared to baseline data (regardless of the amount of dB shift).

[1] Calculated cumulative sound exposure level = Reported SPL + 10 log (Duration)

[2] Hearing specialist, fishes with a swim bladder involved in hearing

As shown in Table 4.1-1, significant threshold shifts were reported in channel catfish (a hearing specialist) when exposed to mid-frequency sonar at a maximum sound pressure level of 210 dB for a total duration of 15 seconds (Halvorsen et al., 2012c). However, the same effect was not observed in rainbow trout (a hearing generalist). Based on limited data, the Navy calculated the cumulative sound exposure level, then rounded down for a final proposed threshold of 220 dB re 1 µPa^{2}s for all hearing specialists (see Table 4.1-2). This threshold is consistent with criteria presented in the *ANSI Sound Exposure Guideline* technical report which is reported in dB RMS. No numeric criteria are proposed for hearing generalists (including fishes without a swim bladder) as species within these fish categories do not sense pressure well and likely cannot hear frequencies above 2 kHz. Furthermore, hearing generalists are less susceptible to hearing impairment from sound exposures compared to hearing specialists (Halvorsen et al., 2012c; Popper et al., 2014).

A hearing specialist and at least one example of a hearing generalist showed signs of TTS after exposure to low-frequency sonars (see Table 4.1-1). Specifically, threshold shifts in channel catfish and rainbow trout were reported after exposure to a maximum received sound pressure level of 193 dB re 1 µPa (criteria presented in the *ANSI Sound Exposure Guideline* technical report) for 324 seconds, but not in largemouth bass or yellow perch (Halvorsen et al., 2013; Popper et al., 2007). Because the results were variable, and because most fishes are sensitive to low-frequency sound, the Navy's threshold for TTS from exposure to low-frequency sonar for all fishes with a swim bladder was rounded down to a cumulative sound exposure level of 210 dB re 1 μPa^2-s (see Table 4.1-2). Furthermore, based on available data and the assumption that generalists are less susceptible to hearing loss than specialists, the onset of TTS is presumed to occur above this proposed threshold for hearing generalists (as evident by the greater than sign).

Table 4.1-2: Thresholds to TTS in Fishes from Sonar

Hearing Group	Fish Category	Mid-Frequency Sonar	Low-Frequency Sonar
Generalists	Fishes without a swim bladder	NC	NC
	Fishes with a swim bladder not involved in hearing	NC	> 210
Specialists	Fishes with a swim bladder involved in hearing	220	210
	Fishes with a swim bladder and with high-frequency hearing[1]	220	210

Notes: cSEL = cumulative sound exposure level (dB re 1 μPa2-s); NC = effects from exposure to sonar are not likely, therefore no criteria are proposed; ">" indicates that the given effect would occur above the reported threshold.

[1] Some species within this category can detect sound pressure up to 10 or 100 kHz. All other fishes have an upper frequency cutoff at 2kHz.

4.1.2 Quantifying Injury and Hearing Impacts from Air Guns and Pile Driving

Criteria and thresholds used to estimate impacts from sound produced by impact pile driving and air gun activities are presented in Table 4.1-3. Consistent with the ANSI Sound Exposure Guideline technical report (Popper et al., 2014), dual metric sound exposure criteria and cumulative sound exposure metrics are utilized to estimate ranges to mortality, non-auditory injury, and TTS (respectively) from impulsive sources.

Table 4.1-3: Sound Exposure Criteria for Air Guns and Pile Driving

Hearing Group	Fish Category	Mortality		Injury		TTS
		cSEL	peak SPL	cSEL	peak SPL	cSEL
Generalists	Fishes without a swim bladder	> 219	> 213	> 216	> 213	NC
	Fishes with a swim bladder not involved in hearing	210	> 207	203	> 207	> 186
Specialists	Fishes with a swim bladder involved in hearing and those with high-frequency hearing[1]	207	> 207	203	> 207	186

Notes: cSEL = cumulative sound exposure level (dB re 1 µPa2-s); peak SPL = average single strike peak sound pressure level (dB re 1 µPa); TTS = temporary threshold shift; NC = effects from exposure to impulsive sources are unlikely, therefore no criteria are proposed; “>” indicates that the given effect would occur above the reported threshold.

Due to the lack of detailed data on injury thresholds in fishes exposed to air guns, thresholds from impact pile driving exposures were used as a proxy for this analysis (Halvorsen et al., 2012a; Halvorsen et al., 2011, 2012b). However, it is important to note that the thresholds derived from pile driving experiments are likely specific to the test conditions under which the criteria were derived, and therefore may not accurately predict ranges to effects from exposure to other impulsive sound sources. As discussed in the *Fishes Acoustic Background* section, injury and mortality in fishes exposed to impulsive sources may vary depending on the presence or absence, and type, of swim bladder. Injury and mortal injury have not been observed in fishes without a swim bladder because of exposure to impulsive sources. Therefore, these effects would likely occur above the thresholds in Table 4.1-3.

Overall, PTS has not been known to occur in fishes. Any hearing loss in a fish may be as temporary as the timeframe required to repair or replace the sensory cells that were damaged or destroyed (Popper et al., 2014; Popper et al., 2005; Smith et al., 2006). The lowest sound exposure level at which TTS has been observed in fishes with a swim bladder involved in hearing is 186 dB re 1 µPa2-s (Popper et al., 2005). Hearing generalists would be less susceptible to hearing loss (i.e., TTS) than hearing specialists, even at higher levels and longer durations. As a result, the proposed interim thresholds in the ANSI Sound Exposure Guideline technical report (Popper et al., 2014) for hearing generalists would be greater than (>) or much greater than (>>) 186 dB re 1 µPa2-s for fishes with a swim bladder not involved and those without a swim bladder, respectively. However, the threshold for TTS for fishes without a swim bladder was not carried forward in this analysis as fishes without a swim bladder generally have not shown signs of TTS from exposure to sound and therefore this effect is considered unlikely to occur.

4.1.3 Quantifying Mortality, Injury, and Hearing Impacts from Explosives

Criteria and thresholds to estimate impacts from sound and energy produced by explosive activities are presented below (Table 4.1-4) These thresholds were applied in the Navy’s previous analysis of impacts in the Study Area. The mortality threshold is the lowest value recommended for explosives in the *ANSI Sound Exposure Guideline* technical report (Popper et al., 2014). The guidelines provide qualitative criteria for injury due to explosives and do not suggest any thresholds. Instead, the peak pressure injury threshold of 220 dB is based on available explosive literature. An explanation of the development of this threshold is provided below. The TTS threshold for fishes with a swim bladder is the value suggested in the guidelines for impulsive sounds other than explosives, as no data on explosive impacts on fish hearing is available. Consistent with the recommendations in the guidelines, fishes without a swim bladder would not be susceptible to TTS and therefore no criteria are proposed.

Table 4.1-4: Sound Exposure Criteria for Fishes Exposed to Underwater Explosives

Hearing Group	Fish Category	Mortality	Injury	TTS
		peak SPL	peak SPL	cSEL
Generalists	Fishes without a swim bladder	229	220	NC
Generalists and Specialists[1]	Fishes with a swim bladder	229	220	> 186

Notes: CSEL = cumulative sound exposure level (dB re 1 µPa2-s); peak SPL = peak sound pressure level (dB re 1 µPa); TTS = temporary threshold shift; NC = effects from exposure to explosives are not likely, therefore no criteria are proposed; ">" indicates that the given effect would occur above the reported threshold.

[1] Fishes with a swim bladder not involved in hearing are considered generalists, fishes with a swim bladder involved in hearing and with high frequency hearing are considered specialists.

It is not appropriate to utilize the SPL or SEL injury thresholds developed for pile driving to estimate impacts from explosives. The peak sound pressure levels reported in the pile driving literature, upon which the guidelines injury thresholds were based, were not actually correlated with injury (Casper et al., 2017; Casper et al., 2013a; Casper et al., 2012; Casper et al., 2013b; Halvorsen et al., 2012a; Halvorsen et al., 2011, 2012b). Rather, these were the highest peak pressures achieved in the test apparatus that produced the specific SELs desired by the researchers. This was done by modifying the number of strikes per exposure while maintaining the same average single strike peak SPL. Injuries were only reported following exposure to many strikes (i.e., the lowest number of strikes in any of these experimental exposures was 960, over exposure durations of 40-60 minutes) and were correlated to cumulative SEL. It is not possible to discern from these datasets what peak pressure would correlate to injury in a single strike exposure, only that it would likely be higher than the peak pressure used in these experiments.

Additionally, sound from pile driving is not directly comparable to that produced by an explosion. It is likely that the much more rapid and sharper pressure changes make exposure to an explosion more injurious than exposures to multiple pile driving strikes of equal energy. The cumulative SEL metric derived for multiple pile driving strikes should not be applied to single explosives or clusters of explosives (with number of impulses several orders of magnitude lower than studied for pile driving). Although the Navy initially considered pile driving thresholds for explosives in the previous analysis, the injury threshold was revised to better analyze explosive impacts as described herein.

While several metrics have been used in the literature to characterize explosive exposure (e.g., peak pressure and impulse), peak pressure is the most consistently documented metric. As a conservative measure, the absolute lowest peak SPL for larval fishes exposed to explosions that resulted in injury (Settle et al., 2002) was selected to represent the threshold to injury. Recent explosive exposure data also support the threshold with reported rates of injury significantly different than controls starting at peak SPLs of 226 dB (Dahl et al., 2020; Jenkins et al., 2022; Jenkins et al., 2023).

The injury threshold is applied to all fishes due to the lack of rigorous data for multiple species. Since thresholds were selected from exposures of larval fishes, this threshold likely overestimates impacts for larger or adult fishes. Additionally, fishes exposed to received levels higher than 220 dB peak SPL have shown no signs of injury (e.g., Gaspin et al., 1976; Settle et al., 2002; Yelverton et al., 1975).

As data from the most recent series of explosive experiments are still being analyzed (Dahl et al., 2020; Jenkins et al., 2022; Jenkins et al., 2023), the Navy will continue to consider newer data sets for potential refinement of this threshold in the future. It is important that the development of future criteria consider statistical analyses when robust data sets are available as selecting the lowest reported received level at which an effect is observed may be an inaccurate representation of potential effects on the environment.

4.2 Impacts Due to Each Acoustic Substressor and Explosives

This section analyzes the potential impacts from acoustic and explosive stressors on fishes. There are many factors that contribute to how a fish will respond to sound, such as the frequency and received sound level, the duration of the sound-producing activity, the animal's behavioral activity at the time of exposure (e.g., feeding, traveling, resting), and proximity of the animal to the source of the sound.

For what is known about the effects of all acoustic substressor and explosives on fishes, refer to the *Fishes Acoustic Background* section. In this analysis, impacts are categorized as mortality, non-auditory injury, temporary hearing loss (temporary threshold shift [TTS]), auditory injury (AINJ, including auditory neural injury), other physiological response (including stress), masking (occurs when a noise interferes with the detection, discrimination, or recognition of other sounds), and behavioral responses.

4.2.1 Impacts from Sonar and Other Transducers

Sonars and other transducers (collectively referred to as sonars in this analysis) emit sound waves into the water to detect objects, safely navigate, and communicate. Sonars are considered non-impulsive and vary in source level, frequency, duration (the total time that a source emits sound including any silent periods between pings), duty cycle (the portion of time a sonar emits sound when active, from infrequent to continuous), beam characteristics (narrow to wide, directional to omnidirectional, downward or forward facing), and movement (stationary or on a moving platform). Additional characteristics and occurrence of sonar and other transducers used under the Proposed Action are described in the *Acoustic Stressors* and *Activity Descriptions* section.

As discussed in the *Fishes Acoustic Background* section, direct injury (e.g., barotrauma) has not been documented in fishes exposed to sonar. Therefore, injury from sonar is highly unlikely and is not considered further in this analysis. Impacts from exposure to sonar could include TTS, masking, physiological response (including stress), and behavioral reactions.

The *Fishes Acoustic Background* section also discusses that different fish species are not equally sensitive to all sound frequencies. Most marine fishes are hearing generalists or lack a swim bladder, including all ESA-listed species within the Study Area, and would be unable to detect frequencies greater than approximately 2 kHz. Therefore, most marine species would not be susceptible to effects (e.g., TTS, behavioral response) from these sound sources. Some marine fishes are hearing specialists (all non-ESA-listed), which are more sensitive to sound detection and potential impacts than other hearing groups; although fishes within this group would still have to be very close to a relatively high-level low-frequency sonar source to experience TTS. Only a few species of shad (all non-ESA-listed) can detect high-frequency sonar (greater than 10 kHz), although the overlap is very limited between high-frequency sonar use and estuarine areas where shad species concentrate. Additionally, sound from high-frequency sonar systems attenuates below detectable levels (i.e., close to or below ambient sound levels) over a short range in shallow water. Thus, most species in the Study Area (including all ESA-listed species) may only detect low-frequency sonar systems with higher source levels within a few kilometers; and most other, less powerful low-frequency sonar systems, at much shorter ranges.

Military readiness activities that involve the use of sonars could occur throughout the Study Area, although use would generally occur in Navy range complexes and testing ranges, or around inshore locations, and specified ports and piers identified in the *Proposed Activities* section. Impacts from sonar to fishes within the Study Area would be limited to systems with energy below 2 kHz, primarily from low-frequency sonars but could also include some broadband and lower mid-frequency sources (less than 2 kHz). These systems could be used throughout the Study Area but would be concentrated in the Hawaii Study Area and SOCAL Range Complex. Some low-frequency sonars could also be utilized in shallow water training ranges or nearshore areas (e.g., San Clemente Island nearshore under training and Pearl Harbor under testing activities), though these systems are typically operated farther offshore, in deeper waters. Overall, low-frequency sources are operated less often than higher frequency sources throughout the Study Area. Although the general impacts from sonar during testing would be similar in severity to those described during training, there is a higher quantity of sonar usage under testing activities and therefore there may be slightly more impacts during testing activities.

Active sonars used in the Study Area that are within the hearing range of marine fishes are unlikely to substantially mask key environmental sounds due to the intermittent and infrequent use of these systems at most locations within the Study Area. High and continuous duty cycle systems may increase the risk of masking for biologically important sounds, including some fish vocalizations, that overlap in frequency over the brief period these systems are used in any given location within the Study Area. Although some species may be able to produce sound at frequencies greater than 2 kHz, most vocal marine fishes communicate well below this frequency, below the range of most Navy sonar sources. For these reasons, any masking effects would be temporary and infrequent.

Although low-frequency systems generally lack the power necessary to generate TTS in fish, a quantitative analysis was performed using the Navy Acoustic Effects Model and varying potential exposure durations (1, 30, 60 and 120 seconds) to estimate ranges to TTS for fishes exposed to Navy sonars. Calculated ranges to TTS from low-frequency sources, regardless of exposure duration (1 to 120 s), resulted in estimated ranges of zero meters for all fishes and therefore TTS is not anticipated.

As discussed in the *Fishes Acoustic Background* section, fishes that can detect sonars could experience physiological responses or behavioral reactions such as startle or avoidance responses, although the relative risk of these effects at any distance from sonars are expected to be low. In fact, available research showed very little response of both captive and wild Atlantic herring (hearing specialists) to sonar (e.g., no avoidance). Such data suggests a low probability of behavioral reactions to sonar for most fishes; therefore, sonar is unlikely to affect fish populations. It is more likely that fish located near, or attracted to, a moving platform operating sonar (e.g., vessel or in-water device), would avoid the source due to the physical presence of the platform. In addition, there is the potential for some low-frequency sonars to mask biologically important sounds, including some fish vocalizations, that overlap in frequency content with the system that is operated. Such effects could limit the distance over which fishes can communicate or detect important signals, or fish may respond by altering their vocalizations to compensate for the noise, but only if the sound source is louder than the biological signals and lasts long enough to impact transmission and receipt of those signals. Due to the transient nature of most sonar operations, impacts, if any, would be localized and infrequent, only lasting a few seconds or minutes. Overall, sonar use is unlikely to impact individuals. If impacts do occur, they are expected to be insignificant; therefore, long-term consequences for fish populations would not be expected.

Conclusions regarding impacts from the use of sonar and other transducers during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.2 Impacts from Air guns

Air guns use bursts of pressurized air to create intermittent, broadband, impulsive sounds which are dominated by lower frequencies. Air gun use by the Navy is limited and is unlike large-scale seismic surveys that use multiple air guns. Characteristics and occurrence of air guns used under the Proposed Action are described in the *Acoustic Stressors* and *Activity Descriptions* section.

Air gun use would occur nearshore in the SOCAL Range Complex under Intelligence, Surveillance, Reconnaissance testing activities, and greater than 3 NM from shore in the Hawaii, Northern and SOCAL Range Complexes under Acoustic and Oceanographic Research testing. Table 4.2-1 shows the number of days in a maximum year that air guns would be estimated to occur during testing activities. Air guns would only be used during a few days per year in any given location within the Study Area. Some testing events could occur in any one of the multiple listed range complexes and therefore the total number of days is distributed between them for the assessment of impacts.

Table 4.2-1: Number of Days per Year Air Guns Could Occur Under Testing Activities

Range Complex	Days per Year
HRC	57
NOCAL	57
SOCAL	43–44

Most marine fishes are generalists and hear primarily below 2 kHz and would be able to detect broadband signals produced by air guns. Exposure of fishes to air guns could result in direct injury, hearing loss, masking, physiological response, or behavioral reactions.

Impulses from air guns lack the strong shock wave and rapid pressure increases known to cause primary blast injury or barotrauma during explosive events and (to a lesser degree) impact pile driving (see the *Fishes Acoustic Background* section for details). Although data from impact pile driving are often used as a proxy to estimate effects to fish from air guns, using such data may not accurately estimate potential impacts due to the differences in the sound characteristics (e.g., the rise times between the two types of impulsive sources). Typically, impact pile driving signals have a much steeper rise time and higher peak pressure than air gun signals.

To determine whether mortality, injury, or TTS would occur from air gun activities, a quantitative analysis was performed using the Navy Acoustic Effects Model to estimate ranges to effects for fishes exposed to air guns. However, modeling resulted in very small, estimated ranges to mortality, injury and TTS (less than 5 m) for the most sensitive fishes (i.e., those with a swim bladder, see Section 4.4.2, Range to Effects for Air Guns, for details). Based on these short, predicted ranges, most fish would likely avoid the source prior to entering the area of effect due to the physical presence of the system or the platform from which the air gun is operated, further reducing the potentials for impacts. Although some individuals could be present within these small footprints, impacts would be limited to the few fish that are co-located with the air guns during operation of the system. The isolated and infrequent use of air guns would further reduce the potential for impacts on individuals.

Due to the brief nature of each pulse (approximately 0.1 second), it is unlikely that fishes within relatively close distance tens to hundreds of meters of the source would experience masking effects. If masking occurred, it is more likely to happen at farther distances from the source where signals may sound continuous. Such effects could limit the distance over which fishes can communicate or detect important signals, or fish may respond by altering their vocalizations to compensate for the noise, but only if the sound source is louder than the biological signals and lasts long enough to impact transmission and receipt of those signals. However, air gun signals at farther distances (e.g., 100s of meters) are unlikely detectable over existing ambient noise levels and thus are unlikely to cause impacts on individuals or populations.

Fishes may exhibit signs of physiological response or alterations in natural behavior. Some fish species with high site fidelity such as reef fish may show initial startle reactions, returning to normal behavioral patterns within a matter of a few minutes. Pelagic and schooling fishes that typically show less site fidelity may avoid the immediate area for the duration of the event. Multiple exposures to individuals (across days) in the offshore portions of the Study Area are unlikely as air guns are not operated in the same areas from day to day, but rather would be utilized in different areas over time. The exception would be the use of air guns at pierside locations, but these tests are rare in any given year further reducing the potential for multiple exposures of individuals.

Due to the limited use and relatively small footprint of air guns, although some individuals may be harmed if they are co-located with air gun activities, impacts on individual fish are expected to be minor and insignificant and long-term population level consequences would not be expected.

Conclusions regarding impacts from the use of air guns during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.3 Impacts from Pile Driving

Fishes could be exposed to sounds from impact (installation only) and vibratory (install and extraction) pile driving during Port Damage Repair training activities at Port Hueneme, California throughout the year (pile driving would not occur during testing activities). Port Damage Repair training activities are made up of multiple events, each which could occur up to 12 times per year. Each training events is comprised of up to seven separate modules, each which could occur up to three iterations during a single event (for a maximum of 21 modules). Training events would last a total of 30 days, of which pile driving is only anticipated to occur for a maximum of 14 days. Sound from pile driving activities could occur over several hours in each day, though breaks in pile driving are taken frequently to reposition the drivers between piles. Depending on where the activity occurs at Port Hueneme, transmission of pile driving noise may be reduced by pier structures. As a standard operating procedure, the Navy performs soft starts at reduced energy during an initial set of strikes from an impact hammer. Soft starts may “warn” fishes and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Soft starts were not considered during the calculation of ranges to effects (see Section 4.4.2, Range to Effects for Air Guns, for details), nor was the possibility that fishes could avoid the construction area. Therefore, not all fishes within the calculated ranges to effects would receive those effects.

Sounds from the impact hammer are impulsive, broadband, and dominated by lower frequencies. The impulses are within the hearing range of fishes. Sounds produced from a vibratory hammer are similar in frequency range as that of the impact hammer, except the levels are much lower than for the impact hammer, especially when extracting piles from sandy, nearshore ground, and the sound is continuous while operating.

Ranges to effects for fishes exposed to impact pile driving were determined using the calculations, sound propagation modeling, and surrogate sound levels described in the Quantitative Analysis TR. Where effects are anticipated to occur above the designated criteria (see Section 4.1.2, Quantifying Injury and Hearing Impacts from Air Guns and Pile Driving), the estimated ranges to that effect would be less than those displayed in the table. Note, sound exposure criteria are based on impulsive pile driving therefore there are only ranges to effects for activities involving the use of impact pile driving. Currently, there are no proposed criteria for vibratory pile driving and therefore these activities are analyzed qualitatively based on available literature and observed reactions.

Due to the static nature of pile driving activities, two exposure times were used when calculating potential range to effects for different types of fish (e.g., transient, or migratory species versus resident species or those with high site fidelity). The calculations for ranges to effects assumed that some transient fishes would likely move through the area during pile driving activities, resulting in low exposure durations. Therefore, range to effects for these species are estimated based on a cumulative exposure time of 5 minutes (60 strikes per minute * 5 minutes = 300 strikes). As shown in Section 4.4.3 (Range to Effects for Pile Driving), estimated ranges to mortality and injury from the largest pile type and size (i.e., up to 20-inch steel piles) was 10 meters, and estimated ranges were shorter for other pile types and sizes. Although it was estimated that TTS could occur within 131 m for some species, TTS would likely occur at shorter distances for other pile types and sizes, and for hearing generalists. Even fishes that are considered hearing specialists would need to remain within this distance for the full exposure duration to receive TTS, which is unlikely as transitory fishes would likely continue to move through the area after initial exposure.

In contrast, calculations for ranges to effects assumed that resident fishes may remain in the area during pile driving activities and therefore would receive a higher cumulative exposure level. As such, ranges were calculated based on an estimated exposure period of one day where the maximum number of piles for a given type and size would be driven in (e.g., for 20-inch steel piles, the analysis assumed up to 30 piles per day * 300 strikes per minute = 9,000 strikes per day). As shown in Section 4.4.3 (Range to Effects for Pile Driving), single day ranges to effects resulted in potential mortality and injury in hearing specialists within 50 and 93 m, respectively, from the largest pile type and size (i.e., up to 20-inch steel piles). Furthermore, it is anticipated that most hearing specialists present in the port for a full day may receive TTS. Based on the ranges in Section 4.4.3 (Range to Effects for Pile Driving), hearing generalists, fishes without a swim bladder, and fishes exposed to other pile types and sizes could also experience similar impacts, but at shorter distances from the source.

The death of an animal would remove them from the population. Removal of individuals with high reproductive potential (e.g., adult females) would result in a larger impact on the overall population than potential loss of many larval or juvenile fishes, which tend to occur in high numbers (i.e., spawning) and have naturally high mortality rates. Exposures that result in non-auditory injuries may limit an animal's ability to find food, communicate with other animals, interpret the surrounding environment, or detect and avoid predators. Impairment of these abilities can decrease an individual's chance of survival or affect its ability to reproduce depending on the severity of the impact.

Considering the standard operating procedure for soft starts, some fishes (both transient and resident) may still avoid the immediate area surrounding pile driving at the onset of the sound exposure. Hearing loss would be most likely to occur in resident fishes, with a lower probability of impacts on transitory species. However, even those that remained in the area for a full day would likely experience some recovery of hearing loss during the pauses in pile driving activity when the driver is repositioned. Fishes that experience hearing loss may have a reduced ability to detect biologically relevant sounds until their hearing recovers (likely within a few minutes to days depending on the amount of threshold shift).

Port Damage Repair activities occur in shallow, nearshore areas where ambient noise levels are already typically high. Port Hueneme is a military port with potentially high ambient noise levels due to vessel traffic and port activities. Given these factors, significant masking is unlikely to occur in fishes due to exposure to sound from impact pile driving or vibratory pile driving/extraction. If masking occurred, it is more likely to happen at farther distances from the source where signals may sound continuous. Such effects could limit the distance over which fishes can communicate or detect important signals, or fish may respond by altering their vocalizations to compensate for the noise, but only if the sound source is louder than the biological signals and lasts long enough to impact transmission and receipt of those signals. As reported during behavioral response experiments using impulsive sources, it is more likely that fish may startle or avoid the immediate area surrounding a pile driving activity or would habituate and return to normal behaviors after initial exposure (see the *Fishes Acoustic Background* section for more details).

Fishes exposed to vibratory driving or extraction would not result in mortality, injury, or TTS based on the low source level and limited duration of these activities. Based on the predicted noise levels, fishes may exhibit other responses such as temporary masking, physiological response, or behavioral reactions. Vibratory pile extraction is more likely than impact pile driving to cause masking of environmental sounds; however, due to its low source level, the masking effect would only be relevant in a small area around the activity. Fishes may also react to by changing their swimming speed, moving away from the source, or not responding at all.

Repeated exposures of individual fishes would be unlikely for transitory species but could occur in resident species due to the highly localized nature of the activity. Multiple exposures over the course of a day could lead to higher order effects (i.e., temporary hearing loss) due to the accumulated energy on the animal, but would most likely lead to an alteration of natural behavior or the avoidance of that specific area.

Overall, most behavioral effects are expected to be short term (seconds or minutes) and localized, and fish would likely return to their natural behavior shortly after exposure. Although some individuals may be impacted, long-term consequences to fish populations (migratory or resident) would not be expected.

Conclusions regarding impacts from the use of pile driving during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.4 Impacts from Vessel Noise

Fishes may be exposed to vessel-generated noise throughout the Study Area. Military readiness activities with vessel-generated noise would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Specifically, Navy vessel traffic in Hawaii is heaviest south of Pearl Harbor, and in Southern California Navy vessel traffic is heaviest around San Diego and roughly within 50 NM of shore, though these activities could occur throughout the Study Area, as described in the *Acoustic*

Habitat section. The four amphibious approach lanes on the coast of central California bordering NOCAL and PSMR near Mill Creek Beach, Morro Bay, Pismo Beach, and Vandenberg Space Force Base are sources of nearshore vessel noise as well. Navy traffic also has clear routes from Hawaii to the Mariana Islands, Japan, and San Diego, and from San Diego north to the Pacific Northwest. Vessel movements involve transits to and from ports to various locations within the Study Area, and many ongoing and proposed activities within the Study Area involve maneuvers by various types of surface ships, boats, and submarines (collectively referred to as vessels), as well as unmanned vehicles. Activities involving vessel movements occur intermittently and are variable in duration, with some activities ranging from a few hours up to two weeks in a particular location. Surface combatant ships (e.g., destroyers, guided missile cruisers, and littoral combat ships) and submarines especially are designed to be quiet to evade enemy detection.

Characteristics of vessel noise are described in the *Acoustic Habitat* section. Moderate- to low-level passive sound sources including vessel noise are unlikely to cause any direct injury or trauma due to characteristics of the sounds and the moderate source levels. Furthermore, vessels are transient and would result in brief periods of exposure.

All fishes would be able to detect vessels which produce continuous broadband noise, with larger vessels producing sound that is dominant in the lower frequencies where fish hearing is most sensitive. Smaller vessels emit more energy in higher frequencies, much of which would not be detectable by fishes. Although hearing loss due to exposure to continuous sound sources has been reported, the test environment for these experiments (i.e., long-term exposures in a small tank or aquaculture facility) is not representative of Navy vessel transits. Injury and hearing loss because of exposure to vessel noise is not discussed further in this analysis.

Best available science on responses to vessel noise, including behavioral responses, stress, and masking, is summarized in the *Fishes Acoustic Background* section. Vessel noise can potentially mask vocalizations and other biologically relevant sounds (e.g., sounds of prey, predators, or conspecifics) that fishes may rely on, especially in nearshore areas where Navy vessel traffic is high (near ports, harbors and within designated shipping lanes). However, existing high ambient noise levels in ports and harbors with non-Navy vessel traffic and in shipping lanes with commercial vessel traffic would limit the potential for masking by naval vessels in those areas. In offshore areas with lower ambient noise, the duration of any masking effects in a particular location would depend on the time in transit by a vessel through an area. Masking by Navy vessel movements would only occur during the timeframe that the Navy vessel is within a detectable range of a fish. Such effects could limit the distance over which fishes can communicate or detect important signals, or fish may respond by altering their vocalizations to compensate for the noise. Some species may also avoid these areas or modify their behavior (e.g., the Lombard effect) to account for the overall increased noise levels in areas of high anthropogenic activity.

Exposure to vessel noise could result in short-term behavioral reactions, physiological response, masking, or no response. Fishes are more likely to react to nearby vessel noise (i.e., within tens of meters) than to vessel noise emanating from a distance. Fishes may experience physiological response from vessel noise, but responses would likely recover quickly as vessels pass by. Although research indicate prolonged reactions could occur from exposure to chronic noise, it is unlikely that the level of Navy vessel movements would provide a meaningful contribution to the elevated ambient noise levels in industrialized areas and shipping channels. It is more likely brief reactions would occur in quiet, open ocean environments to passing vessels.

Overall, impacts from vessel noise would be temporary and localized, and such responses would not be expected to compromise the general health or condition of individual fish. Therefore, long-term consequences for populations are not expected.

Conclusions regarding impacts from activities that produce vessel noise during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.5 Impacts from Aircraft Noise

Fishes may be exposed to aircraft-generated noise throughout the Study Area. Military readiness activities with aircraft would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Fixed- and rotary-wing (e.g., helicopters) aircraft are used for a variety of military readiness activities throughout the Study Area. Tilt-rotor impacts would be like fixed-wing or rotary-wing aircraft impacts depending on which mode the aircraft is in. Most of these sounds would be concentrated around airbases and fixed ranges within each of the range complexes. Aircraft noise could also occur in the waters immediately surrounding aircraft carriers at sea during takeoff and landing or directly below hovering rotary-wing aircraft that are near the water surface.

Aircraft produce extensive airborne noise from either turbofan or turbojet engines. An infrequent type of aircraft noise is the sonic boom, produced when the aircraft exceeds the speed of sound. Rotary-wing aircraft produce low-frequency sound and vibration (Pepper et al., 2003). Transmission of sound from a moving airborne source to a receptor underwater is influenced by numerous factors, but significant acoustic energy is primarily transmitted into the water directly below the craft in a narrow cone, as discussed in detail in the *Acoustic Primer* section. Underwater sounds from aircraft are strongest just below the surface and directly under the aircraft.

Sounds from aircraft activities, including occasional sonic booms, lack the amplitude or duration to cause injury in fishes underwater. Furthermore, aircraft noise would only result in brief periods of exposure that lack the duration and cumulative energy necessary to cause hearing loss. Due to the brief and dispersed nature of aircraft overflights, the risk of masking is very low. If masking occurred, it would only be during periods of time where a fish is near the surface while directly under a hovering rotary-wing aircraft or aircraft overflight.

In most cases, exposure of fishes to fixed-wing aircraft presence and noise would be brief as the aircraft quickly passes overhead. Supersonic flight at sea is typically conducted at altitudes exceeding 30,000 ft., limiting the number of occurrences of supersonic flight being audible at the water surface. Because most aircraft would pass quickly overhead and rotary-wing aircraft may hover for a few minutes at a time over the ocean, fish at or near the surface have the highest likelihood of exposure to sound.

Due to their low sound levels in water, fixed-wing aircraft or transiting rotary-wing aircraft may not be detectable beyond a short distance (10s of meters) beneath the flight path and therefore it is unlikely that most fish would respond. Those that do respond would likely startle or avoid the immediate area. Daytime and nighttime activities involving rotary-wing aircraft may occur for extended periods of time, up to a couple of hours in some areas, potentially increasing the overall risk of noise exposure. During these activities, rotary-wing aircraft would typically transit throughout an area and may hover over the water. Longer activity durations and periods of time where rotary-wing aircraft hover may increase the potential for behavioral reactions, startle reactions, and physiological response. Low-altitude flights of rotary-wing aircraft during some activities, which often occur under 100 ft. altitude, may elicit a stronger response due to the proximity of a rotary-wing aircraft to the water; the slower airspeed and longer exposure duration; and the downdraft created by a rotary-wing aircraft's rotor.

Overall, if fish were to respond to aircraft noise, only short-term behavioral or physiological response would be expected. Therefore, impacts on individuals would be unlikely and long-term consequences for populations are not expected.

Conclusions regarding impacts from activities that produce aircraft noise during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.6 Impacts from Weapon Noise

Fishes may be exposed to sounds caused by the firing of weapons, objects in flight, and inert impact of non-explosive munitions on the water surface. Military readiness activities using weapons and deterrents would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections*.* The locations where gunnery and other munitions may be used are shown in the *Munitions* data section. Most weapons noise is attributable to Gunnery activities. The overall proposed use of large caliber gunnery has decreased since the prior analysis, whereas medium caliber gunnery would be similar. Most activities involving large caliber naval gunfire or other munitions fired or launched from a vessel are conducted more than 12 NM from shore. The Navy will implement mitigation to avoid or reduce potential impacts from weapon firing noise during Large-Caliber Gunnery activities, as discussed in the *Mitigation* section. For explosive munitions, only associated firing noise is considered in the analysis of weapons noise. The noise produced by the detonation of explosive weapons is analyzed separately.

In general, noise from weapons firing is considered impulsive sound and is generated in close vicinity to, or at the water surface, except for weapons that are launched underwater. Fishes at the surface of the water, in a narrow footprint under a weapons trajectory, could be exposed to naval gunfire sound. Sound due to Missile and Target Launches is considered non-impulsive and is typically at a maximum during initiation of the booster rocket and rapidly fades as the missile or target travels downrange. Furthermore, many missiles and targets are launched from aircraft, which would produce minimal sound in the water due to the altitude of the aircraft at launch. Objects that are dropped and impact the water with great force could produce a loud broadband sound at the water surface. Large-caliber non-explosive projectiles, non-explosive bombs, and intact missiles and targets could also produce a large impulse upon impact with the water surface. These activities would have the highest potential for impacts on nearby fishes. Although reactions by fishes to these specific stressors have not been recorded, fishes would be expected to react to weapons noise, as they would other transient sounds.

Sound from these sources generally lack the duration and high intensity to cause mortality or injury therefore, these effects are not discussed further. Although TTS could potentially occur, the probability is very low of a non-explosive munition landing within a few meters of a fish while it is near the surface. Animals within the area may hear the impact of objects on the surface of the water and would likely alert, dive, or avoid the immediate area. Due to the brief and dispersed nature of weapons noise, masking is also unlikely and not discussed further in this analysis.

Overall, fishes that are exposed to weapons noise may only exhibit brief behavioral reactions such as startle reactions or avoidance, or no reaction at all. Due to the short-term, transient nature of gunfire and launch activities, animals may be exposed to multiple shots within a few seconds but are unlikely to be exposed multiple times within a short period (minutes or hours) as fish would likely avoid the area after initial exposure to these sounds. Behavioral reactions, if they occur, would likely be short term (minutes) and are unlikely to lead to substantial costs or long-term consequences for individuals or populations.

Conclusions regarding impacts from activities that produce weapons noise during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.2.7 Impacts from Explosives

Fishes may be exposed to sound and energy from explosions in the water and near the water surface associated with the proposed activities. Activities using explosives would be conducted as described in the *Proposed Activities* and *Activity Descriptions* sections. Most explosive activities would occur in the SOCAL Range Complex, the Hawaii Study Area, and PMSR, although activities with explosives would also occur in other areas as described in the *Activity Descriptions* section. Most activities involving in-water explosives associated with large caliber naval gunfire, or the launching of targets, missiles, bombs, or other munitions, are conducted more than 12 NM from shore. Small Ship Shock Trials could occur in the SOCAL Range Complex greater than 12 NM from shore as shown in the *Proposed Activities* section. Sinking Exercises are conducted greater than 50 NM from shore as shown in the *Proposed Activities* section. Certain activities with explosives may be conducted close to shore at locations identified in the *Activity Descriptions* section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS. This includes certain Mine Warfare and Expeditionary Warfare activities. In the Hawaii Study Area explosive activities could occur at specified ranges and designated locations around Oahu, including the Puuloa Underwater Range and designated locations in and near Pearl Harbor. In the SOCAL Range Complex, explosive activities could occur near San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast.

Characteristics, quantities, and net explosive weights of in-water explosives used during military readiness activities are provided in the *Acoustic Stressors* section. The use of in-water explosives would increase from the prior analysis for training activities, and would decrease slightly for testing. There is an overall reduction in the use of most of the largest explosive bins (bin E8 [> 60–100 pounds (lb.) net explosive weight (NEW)] and above) for training, and a decrease in two of the largest explosive bins (bin E10 [> 250–500 lb. NEW] and E11 [> 500–650 lb. NEW]) under testing activities. There would be notable increases in the smaller explosive bins (E7 [> 20–60 lb. NEW] and below) under training and testing activities, with the exception of bin E1 (0.1–0.25 lb. NEW) which would decrease under testing activities. Small Ship Shock Trials (bin E16 [> 7,250–14,500 lb. NEW]) not previously analyzed are currently proposed under testing activities. Although the general impacts from explosives during training would be similar in severity to those described during testing, there is a higher quantity of explosives used under training activities and therefore there may be slightly more impacts.

The types of activities with detonations below the surface include Mine Warfare, activities using explosive torpedoes, and ship shock trials, as well as specific training and testing activities. Most explosive munitions used during military readiness activities, however, would occur at or just above the water surface (greater than 90 percent by count). These include those used during surface warfare activities, such as explosive gunnery, bombs, and missiles. Certain nearshore activities use explosives in the surf zone up to the beach, where most explosive energy is released in the air (refer to Appendix H, Description of Systems and Ranges, for location details). In the below quantitative analysis, impacts on fishes are over-estimated because in-air near surface and surf zone explosions are modeled as underwater explosions, with all energy assumed to remain in the water. Sound and energy from in-air detonations at higher altitudes would be reflected at the water surface and therefore are not analyzed further in this section and would have no effect on fishes

Note, the Action Proponents will implement mitigation to avoid impacts from explosive military readiness activities on shallow-water coral reefs, artificial reefs, live hard bottom, submerged aquatic vegetation, and shipwrecks throughout the Study Area (see the *Mitigation* section for details), which consequently, will help avoid potential impacts on fishes that shelter and feed within those habitats.

Sound and energy from explosions could result in mortality and injury, on average, for hundreds or thousands of meters from some of the largest explosions (see Section 4.4.4, Range to Effects for Explosives). Generally, explosives that belong to larger bins (with large net explosive weights) and those calculated based on SPL sound exposure criteria (for single detonations) produce longer ranges within each effect category. However, some ranges vary depending upon several other factors (e.g., cluster size, depth of the water, depth of the charge, etc.) Fishes without a swim bladder, adult fishes, and larger species would generally be less susceptible to injury and mortality from sound and energy associated with explosive activities than small, juvenile, or larval fishes. Additionally, fish may experience brief periods of masking, physiological response, or behavioral reactions, depending on the level and duration of exposure.

The death of an animal would remove them from the population. Removal of individuals with high reproductive potential (e.g., adult females) would result in a larger impact on the overall population than potential loss of many larval or juvenile fishes, which tend to occur in high numbers (i.e., spawning) and have naturally high mortality rates. Exposures that result in non-auditory injuries may limit an animal's ability to find food, communicate with other animals, interpret the surrounding environment, or detect and avoid predators. Impairment of these abilities can decrease an individual's chance of survival or affect its ability to reproduce depending on the severity of the impact. Though TTS can impair an animal's abilities, individuals may recover quickly with little significant effect. Based on available research, any present hearing effects may be accompanied by higher order impacts such as barotrauma or other internal injuries (e.g., inner ear tissue) with the likelihood of these reactions decreasing with increasing distance from the source (see the *Fishes Acoustic Background* section for details).

Fish could also experience masking, physiological response, and behavioral reactions within or beyond the estimated ranges to injury or TTS, with the likelihood of response lower at farther distances from the source (thousands of meters). Due to the nature of single explosive detonations, masking would be unlikely, and any stress or behavioral reactions would be brief (seconds to minutes) during the onset of the explosive signal. Multiple detonations that occur within a few seconds could pose an increased risk of impacts on nearby fishes, though many would likely avoid the source during the first few impulses. Although clustered shots could result in a higher risk of masking, this would likely happen at farther distances from the source where individual detonations might sound more continuous. If an individual fish were repeatedly exposed throughout a day or over multiple days to sound and energy from in-water explosions that caused alterations in natural behavioral patterns or physiological response, these impacts could lead to long-term consequences for the individual such as reduced survival, growth, or reproductive capacity depending on the overall severity and duration of the exposure.

Overall, military readiness activities involving explosions are generally dispersed in space and time. Consequently, repeated exposure of individual fishes to sound and energy from in-water explosions over the course of a day or multiple days is unlikely. Exposure to multiple detonations over the course of a day would most likely lead to an alteration of natural behavior or the avoidance of that specific area. However, most behavioral effects are expected to be short term (seconds or minutes) and localized, regardless of the size of the explosion. Non-injurious impacts are expected to be short-term, and fish would likely return to their natural behavior shortly after exposure. Although some individuals may be impacted, long-term consequences to fish populations would not be expected.

Conclusions regarding impacts from the use of explosives during military readiness activities for ESA-listed species is provided in Section 4.3 (ESA-Listed Species Impact Assessments).

4.3 ESA-Listed Species Impact Assessments

This section relies on the analysis of acoustic and explosive stressors on fish populations described above in Section 4.2 (Impacts Due to Each Acoustic Substressor and Explosives). Available research on reactions of fishes to underwater sound largely suggest that different species may respond similarly to the same sound source, especially similar types of fishes (e.g., migratory versus resident) and those that share similar anatomical features (see the *Fishes Acoustic Background* section). Although many of the ESA-listed species present in the Study Area may overlap locations where acoustic and explosive stressors occur (see the *Fishes Background* section for details*)*, several acoustic substressors (sonar, vessel, aircraft, and weapons noise) were determined to have minor and insignificant effects on fish populations. For example, injurious effects have not been reported in fishes exposed to non-impulsive, tonal, or broadband signals. This is because the characteristics of these non-impulsive sources lack the amplitude and the overall duration to result in physical damage. Therefore, it is not anticipated that non-impulsive acoustic stressors would result in injurious effects to ESA-listed species.

Overall, the described effects from these substressors would be minor, are unlikely to lead to a significant disruption of normal behavioral patterns such as breeding, feeding, or sheltering, and are unlikely to lead to harm. Impacts would be short-term for individuals and long-term consequences for populations would not be expected. Therefore, sonar, vessel, aircraft, and weapons noise are not analyzed further for each ESA-listed species below, but rather rely on the analysis provided above in Section 4.2 (Impacts Due to Each Acoustic Substressor and Explosives).

ESA-listed Chinook and coho salmon, eulachon, and green sturgeon would only occur in the northern portion of the California Study Area, far north of Port Hueneme where pile driving activities occur. Although some southern populations of steelhead could occur in the nearby coastal areas surrounding Port Hueneme, it is not likely that steelhead would enter the port itself as it is a highly developed commercial and military harbor, and would not provide suitable habitat for migrating steelhead to and from their natal rivers. Additionally, giant manta rays, oceanic whitetip and scalloped hammerhead sharks would only occur in Southern California (i.e., the SOCAL Range Complex), south of the location for pile driving activities. Therefore, due to lack of geographic overlap with the stressor, pile driving is not analyzed further.

Air guns and explosives could potentially effect ESA-listed fishes that overlap in space and time with these stressors. As such, a full analysis is provided for each ESA-listed species in the sections below. Additionally, an assessment of the overlap and potential pathways for effects with designated critical habitat for green sturgeon is provided as a small portion of the critical habitat overlaps the Study Area. Critical habitat for all other ESA-listed species do not overlap spatially with the HCTT Study Area, and are not analyzed further.

4.3.1 Chinook Salmon (*Oncorhynchus tshawytscha*) – Threatened, Endangered

The California Coastal, Central Valley spring-run, and Sacramento River winter-run ESU of Chinook salmon could occur in the NOCAL Range Complex throughout the year depending on various population migration timing. Although Chinook salmon tend to move north, outside of the California Study Area after entering the marine environment (Bellinger et al., 2015; Crozier et al., 2019; Moyle et al., 2017; Satterthwaite et al., 2015; Satterthwaite et al., 2014), catch data suggest some limited occurrence of Chinook salmon from the California Coastal and Central Valley spring-run ESUs in the northern most part of the PMSR (south of Monterey Bay, see Bellinger et al., 2015, for details). However, presence of migrating Chinook salmon in this portion of the Study Area would likely be localized, infrequent and temporary. Juvenile Chinook salmon would only occur in nearshore environments, outside of the Study Area. Adult Chinook salmon generally prefer nearshore, coastal waters along the shelf and are less often found over the continental slope or basin habitats as supported by tag data from the Gulf of Alaska (Seitz & Courtney, 2022, 2023, 2024).

Chinook salmon may be exposed to sound from air guns associated with testing activities in the NOCAL Range Complex (air guns are not used during training activities and are not used in the PMSR). As summarized in Table 4.2-1, air guns would be used up to 57 days per year in this portion of the Study Area. Exposures to air guns would be highly dependent on the co-occurrence of adult and juvenile Chinook salmon during the limited timeframe air guns are used, which is further limited for some of the ESUs described here as their migration over the continental shelf would be temporary and localized. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality, injury, and TTS are highly unlikely to occur. Furthermore, Chinook salmon are considered hearing generalists, therefore any TTS that could occur would be anticipated at distances shorter than those reported in Section 4.4.2 (Range to Effects for Air Guns). If exposures occur, Chinook salmon may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and Chinook salmon would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Chinook salmon could also be exposed to sound and energy from explosives associated with military readiness activities in the NOCAL Range Complex, and potentially the northernmost part of the PMSR. Juvenile Chinook salmon would remain close to shore and would not be present in the Study Area, and therefore would not be exposed to explosive activities. Overall, there are very few activities that utilize explosives in the NOCAL Range Complex compared to other locations and, the munitions used during these activities are considered small (E3 [> 0.5–2.5 lb. NEW] or below). Explosive activities are generally dispersed in space and time reducing the likelihood that explosions would co-occur with individual Chinook salmon. In the NOCAL Range Complex, all explosive activities will be conducted at least 12 NM from the closest point of land, which will avoid or reduce impacts on Chinook salmon present in nearshore habitats. Due to the infrequent and isolated use of explosives in this portion of the Study Area, potential impacts on Chinook salmon would be minimal.

Although there are higher quantities of explosives used in the PMSR compared to the NOCAL Range Complex, explosive activities are generally dispersed in space and time reducing the likelihood that explosions would co-occur with individual Chinook salmon. Furthermore, most of the explosive munitions used in this location are considered small (E5 [> 5–10 lb. NEW] or below). Some Chinook salmon could also be exposed to large detonations during activities such as oceanographic research (E7

[> 20–60 lb. NEW]) and Torpedo Testing (E8 [> 60–100 lb. NEW] or E11 [> 500–675 lb. NEW]). However, these larger detonations are typically used beyond 12 NM from shore, reducing the potential overlap for Chinook that may occur farther south and closer to shore. Furthermore, large detonations are used much less often than smaller ones, reducing the potential for overlap with migrating salmon.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, Chinook salmon that are co-located with explosive activities in these described areas may experience TTS, injury or mortality. The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, Chinook salmon are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. If a school of salmon were present within the vicinity of an explosive, this could result in a larger number of individuals affected depending on their proximity to the source. Although some individuals may be impacted, long-term consequences to ESA-listed chinook salmon are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, may affect, but are not likely to adversely affect, the California Coastal, Central Valley spring-run, and Sacramento River winter-run ESU of Chinook salmon. The use of explosives during training activities, may affect, and are likely to adversely affect, each ESU of Chinook salmon. Activities that involve the use of pile driving are not applicable to Chinook salmon because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, may affect, but are not likely to adversely affect, the California Coastal, Central Valley spring-run, and Sacramento River winter-run ESU of Chinook salmon. The use of explosives during testing activities, may affect, and are likely to adversely affect, each ESU of Chinook salmon. Pile diving activities are not conducted during testing.

4.3.2 Coho Salmon (*Oncorhynchus kisutch*) – Threatened, Endangered

The Oregon Coast, Southern Oregon and Northern California Coast, and Central California Coast ESU of coho salmon could occur in the NOCAL Range Complex throughout the year depending on various population migration timing. Survey data suggest coho salmon largely occur along the shelf in coastal, nearshore habitats and are widely dispersed with lower abundances in deeper, offshore waters (Harding, 2015). Juvenile coho salmon are likely to remain closer to shore than subadults and adults and are typically distributed in the uppermost portion of the water column (i.e., within the first ~10 m) whereas adults would occur at deeper depths (up to 50 m) (Pearcy & Fisher, 1988).

Coho salmon may be exposed to sound from air guns associated with testing activities in the NOCAL Range Complex (air guns are not used during training activities). As summarized in Table 4.2-1, air guns would be used on up to 57 days per year in this portion of the Study Area. Exposures to air guns would be highly dependent on the co-occurrence of coho salmon during the limited timeframe air guns are used, which is further limited for some of the ESUs described here as their migration over the continental shelf would be temporary and localized. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality, injury, and TTS are highly unlikely to occur. Furthermore, coho salmon are considered hearing generalists, therefore any TTS that could occur would be anticipated at distances shorter than those reported in in Section 4.4.2 (Range to Effects for Air Guns). If exposures occur, coho salmon may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and coho salmon would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Coho salmon could also be exposed to sound and energy from explosives associated with military readiness activities in the NOCAL Range Complex. Juvenile coho salmon that remain close to shore would not likely be exposed to explosive activities in this portion of the Study Area. Although subadult and adult coho salmon may be exposed to detonations placed throughout the water column (i.e., near the surface to depths of 50 m), they are very surface oriented and therefore are more likely to be exposed to explosives detonated in the upper portion of the water column, or those at the water surface. Overall, there are very few activities that utilize explosives in the NOCAL Range Complex compared to other locations and, the munitions used during these activities are considered small (E3 [> 0.5–2.5 lb. NEW] or below). Explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual coho salmon. In the NOCAL Range Complex, any explosive activities will be at least 12 NM from the closest point of land, which will avoid or reduce impacts on coho that are present in nearshore, coastal habitats. Due to the infrequent and isolated use of explosives in this portion of the Study Area, potential impacts on coho salmon would be minimal.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, coho salmon that are co-located with explosive activities in these described areas may experience TTS, injury or mortality. The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, coho salmon are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. If a school of salmon were present within the vicinity of an explosive, this could result in a larger number of individuals affected depending on their proximity to the source. Although some individuals may be impacted, long-term consequences to ESA-listed coho salmon are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, <u>may affect, but are not likely to adversely affect</u>, the Oregon Coast, Southern Oregon and Northern California Coast, and Central California Coast ESU of coho salmon. The use of explosives during training activities, <u>may affect, and are likely to adversely affect</u>, each ESU of coho salmon. Activities that involve the use of pile driving are <u>not applicable</u> to coho salmon because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, may affect, but are not likely to adversely affect, the Oregon Coast, Southern Oregon and Northern California Coast, and Central California Coast ESU of coho salmon. The use of explosives during testing activities, may affect, and are likely to adversely affect, each ESU of coho salmon. Pile diving activities are not conducted during testing.

4.3.3 Steelhead (*Oncorhynchus mykiss*) – Threatened, Endangered

The Northern California, California Central Valley, Central California Coast, South-Central California Coast, and Southern California DPS of steelhead could occur in the California Study Area throughout the year depending on various population migration timing. Based on the location of their natal streams and the tendency to migrate north along the coast of California, it is possible that steelhead from each of the listed DPSs could occur in the NOCAL Range Complex. Steelhead from the Central California Coast, South-Central California Coast and Southern California DPS could also occur in PMSR, with steelhead from the South-Central California Coast and Southern California DPS also present in the SOCAL Range Complex. Although some steelhead may occur farther offshore in open ocean areas for rearing and foraging, adult and juvenile steelhead are more likely to be present in nearshore, coastal areas or along the continental shelf during migration to and from their natal streams. Both adults and juveniles are strongly surface oriented and generally occur within the top 2 m of the water column. Juveniles from some populations would likely remain in freshwater habitats, limiting the potential overlap with explosive activities in the Study Area.

Steelhead may be exposed to sound from air guns associated with testing activities in the NOCAL and SOCAL Range Complex (air guns are not used during training activities or in the PMSR). As summarized in Table 4.2-1, air guns would be used on up to 57 and 44 days per year in the NOCAL and SOCAL Range Complexes, respectively. Exposures to air guns would be highly dependent on the co-occurrence of steelhead during the limited timeframe air guns are used, which is further limited for some of the DPSs described here as their migration over the continental shelf would be temporary and localized. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality, injury, and TTS are highly unlikely to occur. Furthermore, steelhead are considered hearing generalists, therefore any TTS that could occur would be anticipated at distances shorter than those reported in in Section 4.4.2 (Range to Effects for Air Guns). If exposures occur, steelhead may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief, and steelhead would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Steelhead could also be exposed to sound and energy from explosives associated with military readiness activities in the NOCAL and SOCAL Range Complexes, and the PMSR. Because steelhead are highly surface oriented, they are most likely to be exposed to explosives detonated in the upper portion of the water column or at the water surface. Overall, there are very few activities that utilize explosives in the NOCAL Range Complex compared to other locations and, the munitions used during these activities are considered small (E3 [> 0.5–2.5 lb. NEW] or below). Explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual steelhead. In the NOCAL Range Complex, any explosive activities will be at least 12 NM from the closest point of land, which will avoid or reduce impacts on steelhead in nearshore habitat areas. Due to the infrequent and isolated use of explosives in this portion of the Study Area, potential impacts on steelhead would be minimal.

Although there are higher quantities of explosives used in PMSR and SOCAL Range Complex compared to the NOCAL Range Complex, explosive activities are generally dispersed in space and time. Most of the explosive munitions used in this location are considered small (E5 [> 5–10 lb. NEW] or below). Some steelhead could also be exposed to large detonations during activities such as oceanographic research (E7 [> 20–60 lb. NEW]) and Torpedo Testing (E8 [> 60–100 lb. NEW] or E11 [> 500–675 lb. NEW]). Overall, large detonations are used much less often than smaller ones, reducing the potential for overlap with migrating steelhead. Additionally, these larger detonations are typically used beyond 12 NM from shore, reducing the potential overlap for steelhead that are present closer to shore. Some exceptions to this include explosives conducted close to shore at locations identified in the *Activity Descriptions* section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS. This includes certain Mine Warfare and Expeditionary Warfare activities In the SOCAL Range Complex (i.e., near San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast). Although some steelhead could overlap amphibious approach lanes in the NOCAL Range Complex and the PMSR, there are no explosives used in these areas so no potential for effect from activities conducted in these specific locations.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, steelhead that are co-located with explosive activities in these described areas may experience TTS, injury or mortality. The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, steelhead are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. If a school of salmon were present within the vicinity of an explosive, this could result in a larger number of individuals affected depending on their proximity to the source. Although some individuals may be impacted, long-term consequences to ESA-listed steelhead are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, <u>may affect, but are not likely to adversely affect</u>, the Northern California Coast, California Central Valley, Central California Coast, South-Central California Coast, and Southern California DPS of steelhead. The use of explosives during training activities, <u>may affect, and are likely to adversely affect</u>, each DPS of steelhead. Activities that involve the use of pile driving are <u>not applicable</u> to steelhead because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, <u>may affect, but are not likely to adversely affect</u>, the Northern California Coast, California Central Valley, Central California Coast, South-Central California Coast, and Southern California DPS of steelhead. The use of explosives during testing activities, <u>may</u>

affect, and are likely to adversely affect, each DPS of steelhead. Pile diving activities are not conducted during testing.

4.3.4 Green Sturgeon (*Acipenser medirostris*) – Threatened

The Southern DPS of green sturgeon could occur in the northern portion of the California Study Area (i.e., the NOCAL Range Complex) throughout the year depending on seasonal migration. Early life stage and juveniles would only be present in freshwater environments, therefore subadults and adults are the only age class likely to occur within the Study Area. Migrations typically occur along the continental shelf within the 110 m depth contour, with most data suggesting green sturgeon are typically found at depths between 40–70 m. However, some sturgeon are known to linger in shallow waters (20 m) after exiting bays and estuaries before departing on their migration route. Although sturgeon spend much of their time on the bottom, some may make occasional vertical ascents to the surface.

Green sturgeon may be exposed to sound from air guns associated with testing activities in the NOCAL Range Complex (air guns are not used during training activities). Although large concentrations of green sturgeon have been observed seasonally within coastal bays and estuaries along the west coast of the US (e.g., San Francisco and Monterey Bay), activities that involve the use of air guns would not occur in these locations. As summarized in Table 4.2-1, air guns would be used up to 57 days a year in the NOCAL Range Complex. Except for the occasional visits to the surface, green sturgeon are largely benthic and therefore are less likely to be exposed to air guns used at or near the water surface. Exposures to air guns would be highly dependent on the co-occurrence of green sturgeon during the limited timeframe air guns are used, which is further limited for the Southern DPS of green sturgeon as their migration over the continental shelf would be temporary and localized. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality, injury, and TTS are highly unlikely to occur. Furthermore, green sturgeon are considered hearing generalists, therefore any TTS that could occur would be anticipated at distances shorter than those reported in in Section 4.4.2 (Range to Effects for Air Guns). If exposures occur, green sturgeon may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and green sturgeon would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Green sturgeon could also be exposed to sound and energy from explosives associated with military readiness activities. Specifically, exposures could occur to migrating adults and subadults in the NOCAL Range Complex. Although large concentrations of green sturgeon have been observed seasonally within coastal bays and estuaries along the west coast of the US (e.g., San Francisco and Monterey Bay), activities that involve the use of explosives would not occur in these locations. Green sturgeon spend most of their time on the seafloor, resulting in the highest potential exposures to detonations placed on the bottom or at depth. However, some individuals that occasionally move throughout the water column could also be exposed to surface or near surface munitions. Overall, there are very few activities that utilize explosives in the NOCAL Range Complex compared to other locations and, the munitions used during these activities are considered small (E3 [> 0.5–2.5 lb. NEW] or below). Explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual green sturgeon. In the NOCAL Range Complex, any explosive activities will be at least 12 NM from the closest point of land, which will avoid or reduce impacts on green sturgeon in nearshore, coastal habitats. Due to the infrequent and isolated use of explosives in this portion of the Study Area, potential impacts on green sturgeon would be minimal.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, green sturgeon that are co-located with explosive activities in these described areas may experience TTS, injury or mortality. The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, sturgeon are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. Although some individuals may be impacted, long-term consequences to ESA-listed green sturgeon are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, may affect, but are not likely to adversely affect, the Southern DPS of green sturgeon. The use of explosives during training activities, may affect, and are likely to adversely affect, green sturgeon. Activities that involve the use of pile driving are not applicable to green sturgeon because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, may affect, but are not likely to adversely affect, the Southern DPS of green sturgeon. The use of explosives during testing activities, may affect, and are likely to adversely affect, green sturgeon. Pile diving activities are not conducted during testing.

Critical Habitat

Much of the designated critical habitat for green sturgeon are restricted to nearshore, coastal, and riverine environments, with only a portion of the habitat that overlaps the northern portion of the California Study Area. Specifically, designated critical habitat overlaps the NOCAL Range Complex approximately 25 miles due west of San Francisco Bay. Military readiness activities that use sonar, air guns, explosives and those that produce vessel, aircraft, and weapons noise could occur in the marine portion of the critical habitat (pile driving activities would not occur within designated critical habitat). Many of the physical and biological features of the critical habitat are generally not applicable to the Study Area since they occur within the riverine habitat for this species. Features that do occur in marine areas within the Study Area include food resources, migratory corridors, and water quality. However, sonars and the production of vessel, aircraft, and weapons noise would be infrequent and transient and would not impact the overall abundance and availability of prey items and would not prevent sturgeon from reaching important habitat features (i.e., act as a barrier for passage). Additionally, there are no pathways for effect from these stressors on water quality. Therefore, these acoustic stressors would have no effect on any of the physical and biological features that have been identified.

Air guns and explosives associated with military readiness activities could injure or kill prey items. However, there are a low number of air guns and explosives used in the NOCAL Range Complex, and the NEW of the explosives used in this area are considered small (E3 [> 0.5–2.5 lb. NEW] or below).

Furthermore, any explosive activities in the NOCAL Range Complex will be at least 12 NM from the closest point of land, which will avoid impacts on green sturgeon prey items in nearshore, coastal habitats. Although some prey items may be impacted, long term population effects on invertebrate populations are not anticipated and there is unlikely to be a measurable reduction in abundance and availability of prey. Although green sturgeon may respond behaviorally to impulsive noise, sound and energy from air guns and explosives would be brief, and dispersed in space and time, and would not act as a physical barrier or prevent access to important habitat features. Lastly, there are no pathways for effect from noise produced by air guns and explosives on water quality. Overall, the use of air guns and explosives are not likely to result in destruction or adverse modification of green sturgeon critical habitat.

Based on the analysis presented above, the use of explosives during training activities, <u>may affect, but are not likely to adversely affect</u>, designated critical habitat for the Southern DPS of green sturgeon. The use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, would have <u>no effect</u> on green sturgeon. Activities that involve the use of pile driving are <u>not applicable</u> to critical habitat for green sturgeon because there is no geographic overlap of this stressor with the habitat. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of explosives during testing activities, <u>may affect, but are not likely to adversely affect</u>, designated critical habitat for the Southern DPS of green sturgeon. The use of sonars, noise produced by air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, would have <u>no effect</u> on green sturgeon. Pile driving activities are not conducted during testing.

4.3.5 EULACHON (*THALEICHTHYS PACIFICUS*) – THREATENED

The Southern DPS of eulachon could occur in the California Study Area (i.e., in the NOCAL Range Complex and the PMSR) throughout the year depending on their migration timing. Eulachon are typically distributed in deeper coastal waters and near benthic habitats in the open ocean at a wide range of depths (i.e., from 20 to 500 m) with an average depth around 150 m.

Eulachon may be exposed to sound from air guns associated with testing activities in the NOCAL Range Complex (air guns are not used during training activities or in the PMSR). As summarized in Table 4.2-1, air guns would be used on up to 57 days a year in this portion of the Study Area. Because eulachon typically occur deeper in the water column (at average depths of 150 m) they are less likely to be exposed to air guns used at or near the water surface. Exposures to air guns would be highly dependent on the co-occurrence of eulachon during the limited timeframe air guns are used. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality and injury are highly unlikely to occur. Furthermore, eulachon do not have a swim bladder and are not susceptible to hearing loss. If exposures occur, eulachon may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief, and eulachon would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Eulachon could also be exposed to sound and energy from explosives associated with military readiness activities in the NOCAL Range Complex and the PMSR. Although eulachon may be exposed to detonations placed throughout the water column (i.e., 20 m from the surface to depths of 500 m), they are more likely to be exposed to explosives detonated at depth (mid-water) due to their preference for near benthic, deep ocean environments. Overall, there are very few activities that utilize explosives in the NOCAL Range Complex compared to other locations and, the munitions used during these activities are considered small (E3 [> 0.5–2.5 lb. NEW] or below). In the NOCAL Range Complex, any explosive activities will be at least 12 NM from the closest point of land, which will avoid or reduce impacts on eulachon in nearshore habitat areas. Due to the infrequent and isolated use of explosives in this portion of the Study Area, potential impacts on eulachon would be minimal. Although there are higher quantities of explosives used in the PMSR compared to the NOCAL Range Complex, explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual eulachon. Furthermore, most of the explosive munitions used in this location are considered small (E5 [> 5–10 lb. NEW] or below). Some eulachon could also be exposed to large detonations during activities such as oceanographic research (E7 [> 20–60 lb. NEW]) and Torpedo Testing (E8 [> 60–100 lb. NEW] or E11 [> 500–675 lb. NEW]). However, large detonations are used much less often than smaller ones, and the majority (over 90%) of explosive munitions used during military readiness activities would occur at or above the water surface, further reducing the potential for overlap with eulachon that are present at depth.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, eulachon that are co-located with explosive activities in these described areas may experience injury or mortality. The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, eulachon are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. Although some individuals may be impacted, long-term consequences to ESA-listed eulachon are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, may affect, but are not likely to adversely affect, the Southern DPS of eulachon. The use of explosives during training activities, may affect, and are likely to adversely affect, eulachon. Activities that involve the use of pile driving are not applicable to eulachon because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, may affect, but are not likely to adversely affect, the Southern DPS of eulachon. The use of explosives during testing activities, may affect, and are likely to adversely affect, eulachon. Pile diving activities are not conducted during testing.

4.3.6 Oceanic Whitetip Shark (*Carcharhinus longimanus*) – Threatened

Oceanic whitetip sharks could occur in southern portions of the Study Area (i.e., the Hawaii Study Area and SOCAL Range Complex) throughout the year. Oceanic whitetip sharks have a clear preference for open ocean waters, away from the continental shelf, and are not likely to occur within the coastal portions of the Study Area. Oceanic whitetip sharks are surface oriented, though they may also travel to deeper depths. It is likely oceanic whitetip sharks would be present during the summer months during seasonal movements to higher latitudes.

Oceanic whitetip sharks may be exposed to sound from air guns associated with testing activities in the Hawaii and SOCAL Range Complexes (air guns are not used during training activities). As summarized in Table 4.2-1, air guns would be used on up to 57 and 44 days per year in the Hawaii Study Area and SOCAL Range Complex, respectively. Although oceanic whitetip sharks are surface oriented, increasing the potential to be exposed to air guns, exposures would be highly dependent on the co-occurrence of sharks during the limited timeframe air guns are used. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality and injury are highly unlikely to occur. Furthermore, oceanic whitetip sharks do not have a swim bladder and are not susceptible to hearing loss. If exposures occur, oceanic whitetip sharks may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and sharks would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Oceanic whitetip sharks could also be exposed to sound and energy from explosives associated with military readiness activities. Specifically, exposures could occur in the Hawaii Study Area and SOCAL Range Complex, as well as the HCTT Transit Corridor. Oceanic whitetip sharks in deeper, offshore waters spend much of their time at the surface, potentially increasing the risk of exposure to surface detonations, though they could be exposed throughout the water column as they also frequent deep ocean waters. Explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual sharks. Most of the explosive munitions used throughout the Study Area (including the HCTT Transit Corridor) would be considered small (E5 (> 5 to 10 lb. NEW) or below). Larger detonation would typically occur farther from shore (beyond 12 NM) where oceanic whitetip sharks are present, however, large explosions would be used much less often than smaller detonations, reducing the risk of exposure. Individual sharks would need to be co-located in time and space during explosive activities for potential impacts to occur. Although some oceanic whitetip sharks may be present where Ship Shock Trials occur, this activity would only be conducted once over a seven-year period.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, oceanic whitetip sharks that are co-located with explosive activities in these described areas may experience injury or mortality (TTS is not anticipated as sharks do not have a swim bladder and are not susceptible to hearing loss). The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, oceanic whitetip sharks are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant.

Although some individuals may be impacted, long-term consequences to ESA-listed oceanic whitetip sharks are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, may affect, but are not likely to adversely affect, oceanic whitetip sharks. The use of explosives during training activities, may affect, and are likely to adversely affect, oceanic whitetip sharks. Activities that involve the use of pile driving are not applicable to oceanic whitetip sharks because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, may affect, but are not likely to adversely affect, oceanic whitetip sharks. The use of explosives during testing activities, may affect, and are likely to adversely affect, oceanic whitetip sharks. Pile diving activities are not conducted during testing.

4.3.7 Scalloped Hammerhead Shark (*Sphyrna lewini*) – Endangered

Scalloped hammerhead sharks could occur in southern portions of the Study Area (i.e., the Hawaii Study Area and SOCAL Range Complex) throughout the year. Sightings of scalloped hammerhead sharks in Southern California are considered rare. If scalloped hammerheads are present within the SOCAL Range Complex, it is anticipated that juveniles may be present in coastal nursery areas, with subadults and adults potentially occupying both coastal and offshore habitats. Adult and juvenile sharks are anticipated to be present throughout the Hawaii Study Area, though movement patterns are restricted throughout the Hawaiian Archipelago. Tag data suggest that female scalloped hammerhead sharks typically remain close to shore, in coastal habitats, while males are dispersed farther offshore, in open ocean environments.

Scalloped hammerhead sharks may be exposed to sound from air guns associated with testing activities in the Hawaii Study Area and SOCAL Range Complex (air guns are not used during training activities). As summarized in Table 4.2-1, air guns would be used on up to 57 and 44 days per year in the Hawaii Study Area and SOCAL Range Complex, respectively. Exposure to air gun activities would be highly dependent on the co-occurrence of sharks during the limited timeframe air guns are used (especially in the SOCAL Range Complex where sightings are rare). Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality and injury are highly unlikely to occur. Furthermore, scalloped sharks do not have a swim bladder and are not susceptible to hearing loss. If exposures occur, scalloped hammerhead sharks may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and sharks would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Scalloped hammerhead sharks could also be exposed to sound and energy from explosives associated with military readiness activities in the Hawaii Study Area, SOCAL Range Complex, and in the HCTT Transit Corridor. However, scalloped hammerhead sharks are considered rare to Southern California waters, reducing the potential to be impacted by explosive activities. Explosive activities are generally dispersed in space and time potentially reducing the likelihood that explosions would co-occur with individual sharks. Most of the explosive munitions used throughout the Study Area (including the HCTT Transit Corridor) would be considered small (E5 (> 5–10 lb. NEW) or below). Larger detonations would typically occur farther from shore (beyond 12 NM) where male scalloped hammerhead sharks are more likely to occur compared to females or juveniles. However, large explosions would be used much less often than smaller detonations, reducing the risk of exposure. Individual sharks would need to be co-located in time and space during explosive activities for potential impacts to occur.

Certain activities with explosives may also be conducted close to shore where scalloped hammerhead sharks could occur, at locations identified in the *Activity Descriptions* section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS. This includes certain Mine Warfare and Expeditionary Warfare activities. In the Hawaii Study Area explosive activities could occur at specified ranges and designated locations around Oahu, including the Puuloa Underwater Range and designated locations in and near Pearl Harbor. Note, scalloped hammerhead sharks that are present within the nearshore mitigation areas surrounding the Hawaiian Islands would be protected as these areas prevent the use of explosives year round or seasonally depending on the location (see the *Mitigation* section for details). In the SOCAL Range Complex, explosive activities could occur near San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast. Although some scalloped hammerhead sharks may be present farther offshore where Ship Shock Trials occur, this activity would only be conducted once over a seven-year period.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, scalloped hammerhead sharks that are co-located with explosive activities in these described areas may experience injury or mortality (TTS is not anticipated as sharks do not have a swim bladder and are not susceptible to hearing loss). The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, scalloped hammerhead sharks are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. Although some individuals may be impacted, long-term consequences to ESA-listed scalloped hammerhead sharks are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, <u>may affect, but are not likely to adversely affect</u>, scalloped hammerhead sharks. The use of explosives during training activities, <u>may affect, and are likely to adversely affect</u>, scalloped hammerhead sharks. Activities that involve the use of pile driving are <u>not applicable</u> to scalloped hammerhead sharks because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, <u>may affect, but are not likely to adversely affect</u>, scalloped hammerhead sharks. The use of explosives during testing activities, <u>may affect, and are likely to adversely affect</u>, scalloped hammerhead sharks. Pile diving activities are not conducted during testing.

4.3.8 Giant Manta Ray (*Manta birostris*) – Threatened

Giant manta rays could occur in the southernmost portions of the Study Area (i.e., the Hawaii Study Area and SOCAL Range Complex) throughout the year. Giant manta rays typically occur in areas of upwelling along the coast, or near islands or offshore pinnacles and seamounts. Typically, seasonal migrations are limited to either the west coast (from Baja to Southern California) or around specific islands of Hawaii and giant manta rays are not anticipated to cross ocean basins. Large seasonal aggregations are known to occur along the Kona coast off the Big Island of Hawaii. In the California Study Area, the SOCAL Range Complex is likely the northern limit of their distribution.

Giant manta rays may be exposed to sound from air guns associated with testing activities in the Hawaii Study Area and SOCAL Range Complex (air guns are not used during training activities). As summarized in Table 4.2-1, air guns would be used on up to 57 and 44 days per year in the Hawaii Study Area and SOCAL Range Complex, respectively. Exposures would be highly dependent on the co-occurrence of rays during the limited timeframe air guns are used. Based on the small, estimated ranges (see Section 4.4.2, Range to Effects for Air Guns), mortality and injury are highly unlikely to occur. Furthermore, giant manta rays do not have a swim bladder and are not susceptible to hearing loss. If exposures occur, Giant manta rays may exhibit impacts such as behavioral reactions or physiological response depending on their proximity to the activity, though reactions would be brief and Giant manta rays would likely return quickly to their normal behavior or avoid the immediate area where the sound source is located. Masking effects are unlikely from single air gun pulses due to the short pulse length but may occur at farther distances from the source (100s of meters) if multiple shots were fired in succession and the signal was detectable above ambient noise levels. Masking at greater distances from the source could temporarily limit the distance over which fishes can communicate or detect important signals. Overall, these described effects would be minor, are unlikely to lead to a significant disruption of normal behavior patterns such as breeding, feeding, or sheltering, and are unlikely to lead to injury.

Giant manta rays could also be exposed to sound and energy from explosives associated with military readiness activities in the Hawaii Study Area and SOCAL Range Complex, though manta ray presence in the SOCAL Range Complex may be limited as Southern California is the northern edge of their distribution. Giant manta rays have the potential to be exposed to detonations placed throughout the water column, including near the surface or on the seafloor. However, manta rays that occur on or near reefs, would be protected from exposure due to mitigation measures that prevent explosives on seafloor resources (see the *Mitigation* section for details). Explosive activities are generally dispersed in space and time, potentially reducing the likelihood that explosions would co-occur with individual manta rays. Most of the explosive munitions used throughout the Study Area would be considered small (E5 [> 5–10 lb. NEW] or below). Larger detonations would typically occur farther from shore (beyond 12 NM) where manta rays are present. However, large explosions would be used much less often than smaller detonations, reducing the risk of exposure. Individual manta rays would need to be co-located in time and space during explosive activities for potential impacts to occur. If seasonal aggregations of manta rays occur in other portions of the Study Area and are within the vicinity of an explosive, a larger number of individuals may be affected from a single event depending on their proximity to the source.

Certain activities with explosives may be conducted close to shore where manta rays could occur, specifically at locations identified in the *Activity Descriptions* section and Appendix H (Description of Systems and Ranges) of the HCTT EIS/OEIS. This includes certain Mine Warfare and Expeditionary Warfare activities. In the Hawaii Study Area explosive activities could occur at specified ranges and designated locations around Oahu, including the Puuloa Underwater Range and designated locations in and near Pearl Harbor. However, giant manta rays present within the nearshore mitigation areas surrounding the Hawaiian Islands, including large aggregations along the Kona coast off the Big Island of Hawaii, would be protected as these areas prevent the use of explosives year-round or seasonally depending on the location (see the *Mitigation* section for details). In the SOCAL Range Complex, explosive activities could occur in nearshore areas surrounding San Clemente Island, in the Silver Strand Training Complex, and in other designated mine training areas along the Southern California coast where manta rays may be present. However, the likelihood of giant manta rays co-occurring with these activities would be limited as the SOCAL Range Complex is likely the northern edge of their distribution. Although giant manta rays do not typically migrate across open ocean environments, some manta rays may also be present in the offshore portion of the SOCAL Range Complex where Ship Shock Trials occur. However, exposures would be unlikely as this activity would only be conducted once over a seven-year period.

Generally, smaller explosive bins produce smaller ranges to higher order effects such as mortality, injury and hearing loss compared to larger bin sizes (see Section 4.4.4, Range to Effects for Explosives, for details). Based on the estimated ranges in Section 4.4.4, giant manta rays that are co-located with explosive activities in these described areas may experience injury or mortality (TTS is not anticipated as rays do not have a swim bladder and are not susceptible to hearing loss). The potential for masking from single or multiple detonations would be low due to the brief duration of an individual detonation. More likely, exposures could lead to physiological response or behavioral reactions. Due to the short duration of explosives, dispersed and infrequent use throughout the ranges, giant manta rays are not likely to be exposed multiple times within a short period and any physiological response or behavioral reactions that do occur are anticipated to be brief (seconds to minutes) and insignificant. Although some individuals may be impacted, long-term consequences to ESA-listed giant manta rays are not expected.

Based on the analysis presented above, the use of sonars, and activities that produce vessel, aircraft, and weapons noise during training activities, <u>may affect, but are not likely to adversely affect</u>, giant manta rays. The use of explosives during training activities, <u>may affect, and are likely to adversely affect</u>, giant manta rays. Activities that involve the use of pile driving are <u>not applicable</u> to giant manta rays because there is no geographic overlap of this stressor with the species occurrence. Air gun activities are not conducted during training.

Based on the analysis presented above, the use of sonars and air guns, and activities that produce vessel, aircraft, and weapons noise during testing activities, <u>may affect, but are not likely to adversely affect</u>, giant manta rays. The use of explosives during testing activities, <u>may affect, and are likely to adversely affect</u>, giant manta rays. Pile diving activities are not conducted during testing.

4.4 RANGE TO EFFECTS

The following section provides the range (distance) over which specific physiological or behavioral effects are expected to occur based on the acoustic and explosive criteria in Section 4.1 (Quantifying Impacts on Fishes from Acoustic and Explosive Stressors), and the acoustic and explosive propagation calculations from the Navy Acoustic Effects Model described in the *Quantitative Analysis TR*. The ranges to effects are shown for representative sonar systems, air guns, and explosive bins from E1 (0.1–0.25 lb. NEW) to E16 (>7,500–14,500 lb. NEW). Ranges are determined by modeling the distance that noise from a source will need to propagate to reach exposure level thresholds specific to a fish hearing group or category that will cause TTS, injury, and mortality. Ranges to effects are utilized to help predict impacts from acoustic and explosive sources.

Tables present median and standard deviation ranges to effects for each fish hearing group or category, source or bin, bathymetric depth intervals of ≤200 m and >200 m to represent areas on an off the continental shelf, exposure duration (sonar), and representative cluster size (air guns and explosives). Ranges to effects consider propagation effects of sources modeled at different locations (i.e., analysis points), seasons, source depths, and radials (i.e., each analysis point considers propagation effects in different x-y directions by modeling 18 radials in azimuthal increments of 20° to obtain 360° coverage around an analysis point). The exception to this is ranges to effects for pile driving, which were calculated outside of the Navy Acoustic Effects Model, do not have variance in ranges, and are not presented as a summary statistic (e.g., median and standard deviation).

Boxplots visually present the distribution, variance, and outlier ranges for a given combination of a source or bin, fish hearing group or category, and effect. On the boxplots, outliers are plotted as dots, the lowest and highest non-outlier ranges are the extent of the left and right horizontal lines respectively that extend from the sides of a colored box, and the 25th, 50th (i.e., median), and 75th percentiles are the left edge, center line, and right edge of a colored box respectively.

4.4.1 Range to Effects for Sonar and Other Transducers

The six representative sonar systems with ranges to effects are not applicable to fishes since they produce sound at frequencies greater than the upper hearing range of most fishes (i.e., > 2 kHz).

4.4.2 Range to Effects for Air Guns

Ranges to effects for air guns were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a fish hearing group or category that would cause TTS, injury, and mortality as described in Section 4.1 (Quantifying Impacts on Fishes from Acoustic and Explosive Stressors). Air gun ranges for injury and mortality are SPL- and SEL-based.

Table 4.4-1: Fishes Ranges to Effects for Air Guns (SPL-based)

Group	Depth	Cluster Size	TTS	INJ	MORT
Fishes without a Swim Bladder	≤200 m	1	NA	< 1 m (0 m)	< 1 m (0 m)
		10	NA	NA	NA
	>200 m	1	NA	< 0 m (0 m)	0 m (0 m)
		10	NA	NA	NA
Fishes with a Swim Bladder (including generalists and specialists)	≤200 m	1	NA	< 2 m (1 m)	< 2 m (1 m)
		10	5 m (1 m)	NA	NA
	>200 m	1	NA	< 2 m (1 m)	< 2 m (1 m)
		10	5 m (2 m)	NA	NA

-INJ and MORT are SPL-based
-TTS ranges for fishes with a swim bladder only and are SEL-based
-Median ranges with standard deviation ranges in parentheses
-NA = not applicable
-No ranges for depths ≤200 m or >200 m unless shown
- < indicates that the range to effects would be less than the provided value

Table 4.4-2: Fishes Ranges to Effects for Air Guns (SEL-based)

Group	Depth	Cluster Size	TTS	INJ	MORT
Fishes without a Swim Bladder	≤200 m	1	NA	NA	NA
		10	NA	0 m (0 m)	0 m (0 m)
	>200 m	1	NA	NA	NA
		10	NA	0 m (0 m)	0 m (0 m)
Fishes with a Swim Bladder (including generalists and specialists)	≤200 m	1	NA	NA	NA
		10	5 m (1 m)	0 m (0 m)	0 m (0 m)
	>200 m	1	NA	NA	NA
		10	5 m (2 m)	0 m (0 m)	0 m (0 m)

-INJ and MORT are SEL-based
-TTS ranges for fishes with a swim bladder only
-Median ranges with standard deviation ranges in parentheses
-NA = not applicable
-No ranges for depths ≤200 m or >200 m unless shown

4.4.3 Range to Effects for Pile Driving

Ranges to effects for impact pile driving were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a fish hearing group or category that would cause TTS, injury, and mortality as described in Section 4.1.2 (Quantifying Injury and Hearing Impacts from Air Guns and Pile Driving). Note, sound exposure criteria are not available for piles driven using the vibratory method, therefore ranges to effects are only estimated for piles driven using impact methods. Modeling for pile driving was done outside of the Navy's Acoustic Affects Model (see the Quantitative Analysis TR for details).

Table 4.4-3: Ranges to Effects for Impact Pile Driving for Transient Fishes (5 Minutes)

Pile Type/Size	Hearing Group	Fish Category	Range to Effects (meters)				
			TTS	Onset of Injury		Onset of Mortality	
			cSEL	cSEL	Peak SPL	cSEL	Peak SPL
12 to 20-inch Timber Round Piles	Generalists	Fishes without a swim bladder	0	0	0	0	0
	Generalists	Fishes with a swim bladder not involved in hearing	< 8	1	0	0	0
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	8	1	0	0	0
12 to 20-inch Steel H-Piles	Generalists	Fishes without a swim bladder	0	0	< 1	0	< 1
	Generalists	Fishes with a swim bladder not involved in hearing	< 38	3	< 2	1	< 2
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	38	3	< 2	2	< 2
12 to 20-inch Steel, Timber, or Composite Round Piles	Generalists	Fishes without a swim bladder	0	< 1	< 2	< 1	< 2
	Generalists	Fishes with a swim bladder not involved in hearing	< 131	10	< 5	3	< 5
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	131	10	< 5	5	< 5

Notes: cSEL = Cumulative sound exposure level, peak SPL = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, < indicates that ranges to effects would be less than the provided value.

Table 4.4-4: Ranges to Effects for Impact Pile Driving for Resident Fishes (1 Day)

Pile Type/Size	Hearing Group	Fish Category	Range to Effects (meters)				
			TTS	Onset of Injury		Onset of Mortality	
			cSEL	cSEL	Peak SPL	cSEL	Peak SPL
12 to 20-inch Timber Round Piles	Generalists	Fishes without a swim bladder	0	1	0	1	0
	Generalists	Fishes with a swim bladder not involved in hearing	< 80	6	0	2	0
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	80	6	0	3	0
12 to 20-inch Steel H-Piles	Generalists	Fishes without a swim bladder	0	< 2	< 1	< 1	< 1
	Generalists	Fishes with a swim bladder not involved in hearing	< 201	15	< 2	5	< 2
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	201	15	< 2	8	< 2
12 to 20-inch Steel, Timber, or Composite Round Piles	Generalists	Fishes without a swim bladder	0	< 13	< 2	< 8	< 2
	Generalists	Fishes with a swim bladder not involved in hearing	< 1,267	93	< 5	32	< 5
	Specialists	Fishes with a swim bladder involved in hearing and high-frequency hearing	1,267	93	< 5	50	< 5

Notes: cSEL = Cumulative sound exposure level, peak SPL = Peak sound pressure level, TTS = Temporary Threshold Shift, NR = no criteria are available and therefore no range to effects are estimated, < indicates that ranges to effects would be less than the provided value.

4.4.4 Range to Effects for Explosives

Ranges to effects for explosives were determined by modeling the distance that sound would need to propagate to reach exposure level thresholds specific to a fish hearing group or category that would cause TTS, injury, and mortality as described in Section 4.1 (Quantifying Impacts on Fishes from Acoustic and Explosive Stressors). The explosive ranges for injury and mortality are SPL-based and ranges for TTS are SEL-based.

The Navy Acoustic Effects Model cannot account for the highly non-linear effects of cavitation and surface blow off for shallow underwater explosions, nor can it estimate the explosive energy entering the water from a low-altitude detonation. Thus, for this analysis, in-air sources detonating at or near (within 10 m) the surface are modeled as if detonating completely underwater at a source depth of 0.1 m, with all energy reflected into the water rather than released into the air. Therefore, the amount of explosive and acoustic energy entering the water, and consequently the estimated ranges to effects, are likely to be overestimated. In the tables below, near surface explosions can occur for bathymetric depth intervals of ≤200 m and >200 m.

Table 4.4-5: Explosive Ranges to Effects for Fishes without a Swim Bladder

Bin	Depth	Cluster Size	TTS	INJ	MORT
E1	≤200 m	1	NA	86 m (4 m)	14 m (4 m)
	>200 m	1	NA	87 m (5 m)	17 m (4 m)
E2	≤200 m	1	NA	136 m (14 m)	37 m (5 m)
	>200 m	1	NA	136 m (14 m)	37 m (6 m)
E3	≤200 m	1	NA	243 m (16 m)	64 m (12 m)
	>200 m	1	NA	247 m (13 m)	73 m (9 m)
E4	≤200 m	1	NA	436 m (26 m)	158 m (13 m)
	>200 m	1	NA	437 m (31 m)	154 m (12 m)
E5	≤200 m	1	NA	416 m (29 m)	148 m (13 m)
	>200 m	1	NA	398 m (25 m)	144 m (9 m)
E6	≤200 m	1	NA	575 m (52 m)	216 m (24 m)
	>200 m	1	NA	575 m (48 m)	221 m (23 m)
E7	≤200 m	1	NA	706 m (24 m)	281 m (10 m)
	>200 m	1	NA	714 m (21 m)	281 m (9 m)
E8	≤200 m	1	NA	912 m (54 m)	357 m (8 m)
	>200 m	1	NA	903 m (47 m)	354 m (10 m)
E9	≤200 m	1	NA	953 m (40 m)	456 m (17 m)
	>200 m	1	NA	957 m (47 m)	458 m (19 m)
E10	≤200 m	1	NA	1,283 m (96 m)	578 m (51 m)
	>200 m	1	NA	1,274 m (112 m)	579 m (48 m)
E11	≤200 m	1	NA	2,042 m (58 m)	738 m (10 m)
	>200 m	1	NA	2,000 m (130 m)	747 m (29 m)
E12	≤200 m	1	NA	1,750 m (5 m)	760 m (2 m)
	>200 m	1	NA	1,707 m (31 m)	749 m (11 m)
E13	≤200 m	1	NA	6,486 m (348 m)	2,972 m (132 m)
E16	>200 m	1	NA	9,576 m (645 m)	3,757 m (168 m)

Median ranges with standard deviation ranges in parentheses, TTS ranges are SEL-based and for fishes with a swim bladder only
TTS = Temporary Threshold Shift, INJ = Injury, MORT = Mortality, NA = not applicable
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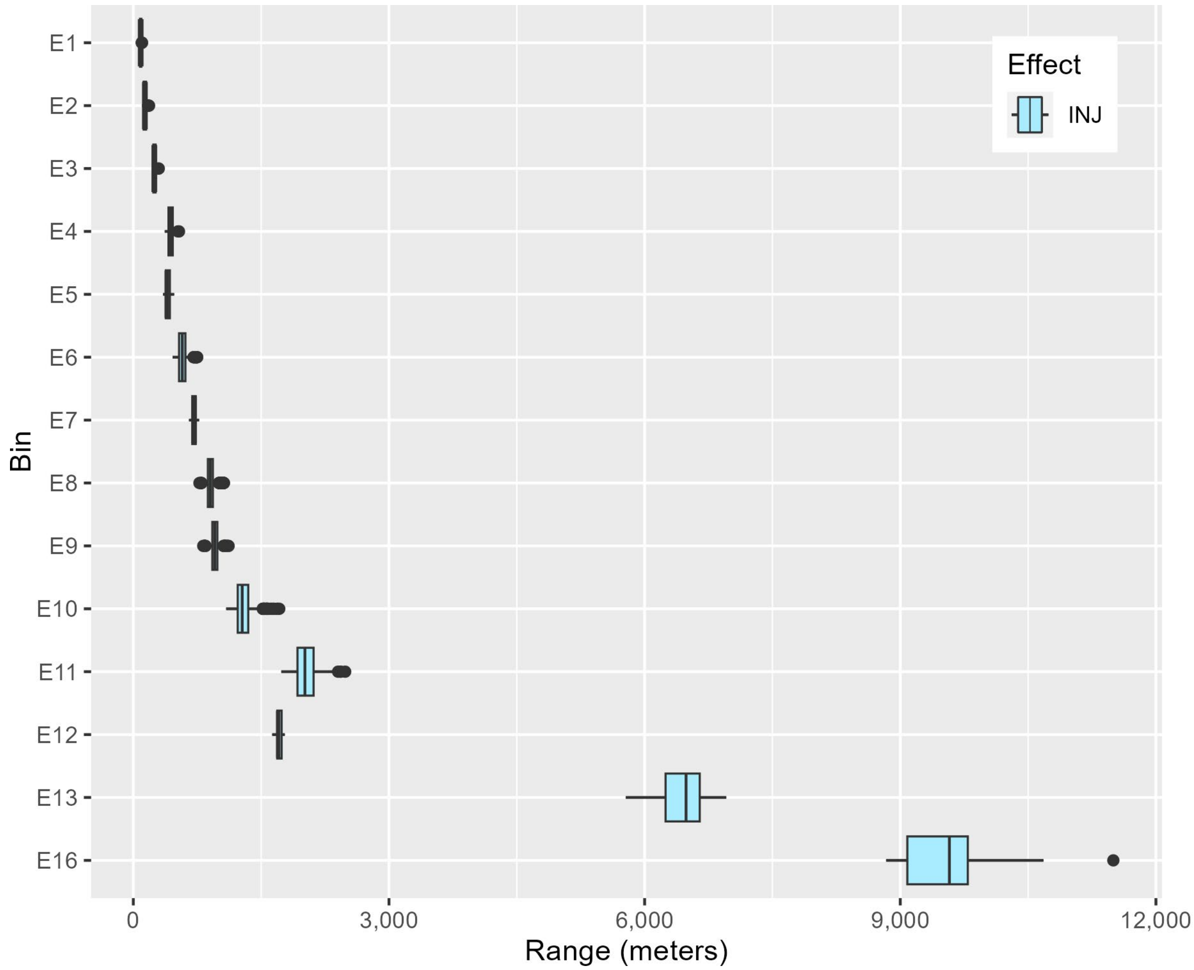

Figure 4.4-1: Explosive Ranges to Injury for Fishes Without a Swim Bladder

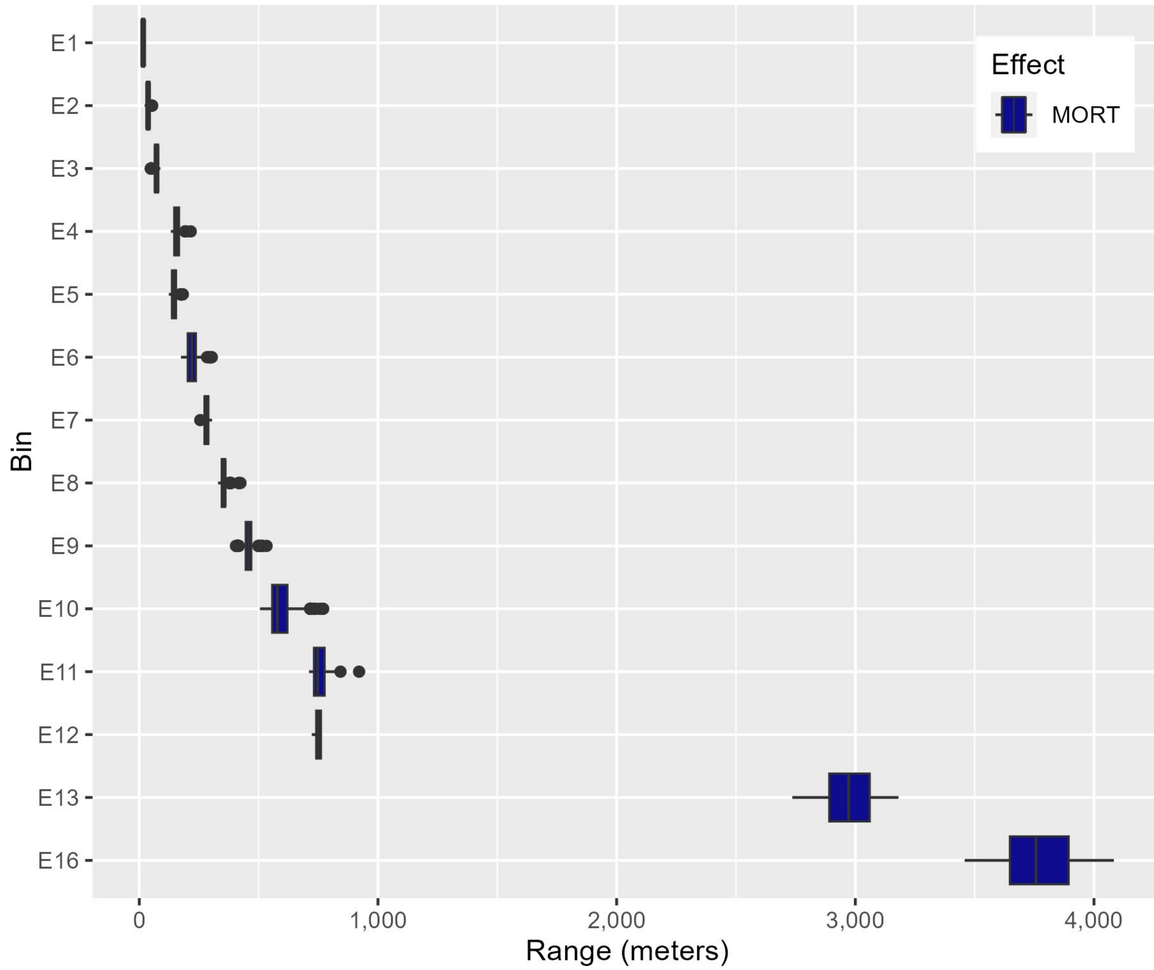

Figure 4.4-2: Explosive Ranges to Mortality for Fishes Without a Swim Bladder

Table 4.4-6: Explosive Ranges to Effects for Fishes with a Swim Bladder

Bin	Depth	Cluster Size	TTS	INJ	MORT
E1	≤200 m	1	< 45 m (7 m)	86 m (4 m)	14 m (4 m)
		5	< 90 m (18 m)	NA	NA
		25	< 187 m (51 m)	NA	NA
		50	< 254 m (33 m)	NA	NA
	>200 m	1	< 2 m (16 m)	87 m (5 m)	17 m (4 m)
		5	< 75 m (22 m)	NA	NA
		25	< 170 m (9 m)	NA	NA
		50	< 240 m (8 m)	NA	NA
E2	≤200 m	1	< 43 m (6 m)	136 m (14 m)	37 m (5 m)
	>200 m	1	< 44 m (7 m)	136 m (14 m)	37 m (6 m)
E3	≤200 m	1	< 96 m (34 m)	243 m (16 m)	64 m (12 m)
		5	< 200 m (75 m)	NA	NA
		25	< 388 m (149 m)	NA	NA
	>200 m	1	< 100 m (22 m)	247 m (13 m)	73 m (9 m)
		5	< 180 m (7 m)	NA	NA
		25	< 390 m (11 m)	NA	NA
E4	≤200 m	1	< 292 m (124 m)	436 m (26 m)	158 m (13 m)
	>200 m	1	< 180 m (17 m)	437 m (31 m)	154 m (12 m)
E5	≤200 m	1	< 160 m (201 m)	416 m (29 m)	148 m (13 m)
		5	< 302 m (58 m)	NA	NA
	>200 m	1	< 140 m (7 m)	398 m (25 m)	144 m (9 m)
		5	< 300 m (9 m)	NA	NA
		20	< 550 m (12 m)	NA	NA
E6	≤200 m	1	< 465 m (315 m)	575 m (52 m)	216 m (24 m)
		15	< 1,827 m (157 m)	NA	NA
	>200 m	1	< 330 m (85 m)	575 m (48 m)	221 m (23 m)

Bin	Depth	Cluster Size	TTS	INJ	MORT
E7	≤200 m	1	< 280 m (56 m)	706 m (24 m)	281 m (10 m)
	>200 m	1	< 270 m (79 m)	714 m (21 m)	281 m (9 m)
E8	≤200 m	1	< 495 m (54 m)	912 m (54 m)	357 m (8 m)
	>200 m	1	< 489 m (48 m)	903 m (47 m)	354 m (10 m)
E9	≤200 m	1	< 625 m (350 m)	953 m (40 m)	456 m (17 m)
	>200 m	1	< 438 m (15 m)	957 m (47 m)	458 m (19 m)
E10	≤200 m	1	< 684 m (124 m)	1,283 m (96 m)	578 m (51 m)
	>200 m	1	< 684 m (126 m)	1,274 m (112 m)	579 m (48 m)
E11	≤200 m	1	< 1,778 m (74 m)	2,042 m (58 m)	738 m (10 m)
	>200 m	1	< 1,806 m (90 m)	2,000 m (130 m)	747 m (29 m)
E12	≤200 m	1	< 676 m (1 m)	1,750 m (5 m)	760 m (2 m)
	>200 m	1	< 676 m (15 m)	1,707 m (31 m)	749 m (11 m)
E13	≤200 m	1	< 7,875 m (202 m)	6,486 m (348 m)	2,972 m (132 m)
E16	>200 m	1	< 10,965 m (491 m)	9,576 m (645 m)	3,757 m (168 m)

Median ranges with standard deviation ranges in parentheses, TTS ranges are SEL-based and for fishes with a swim bladder only
TTS = Temporary Threshold Shift, INJ = Injury, MORT = Mortality, NA = not applicable, < indicates that ranges to effects would be less than the provided value
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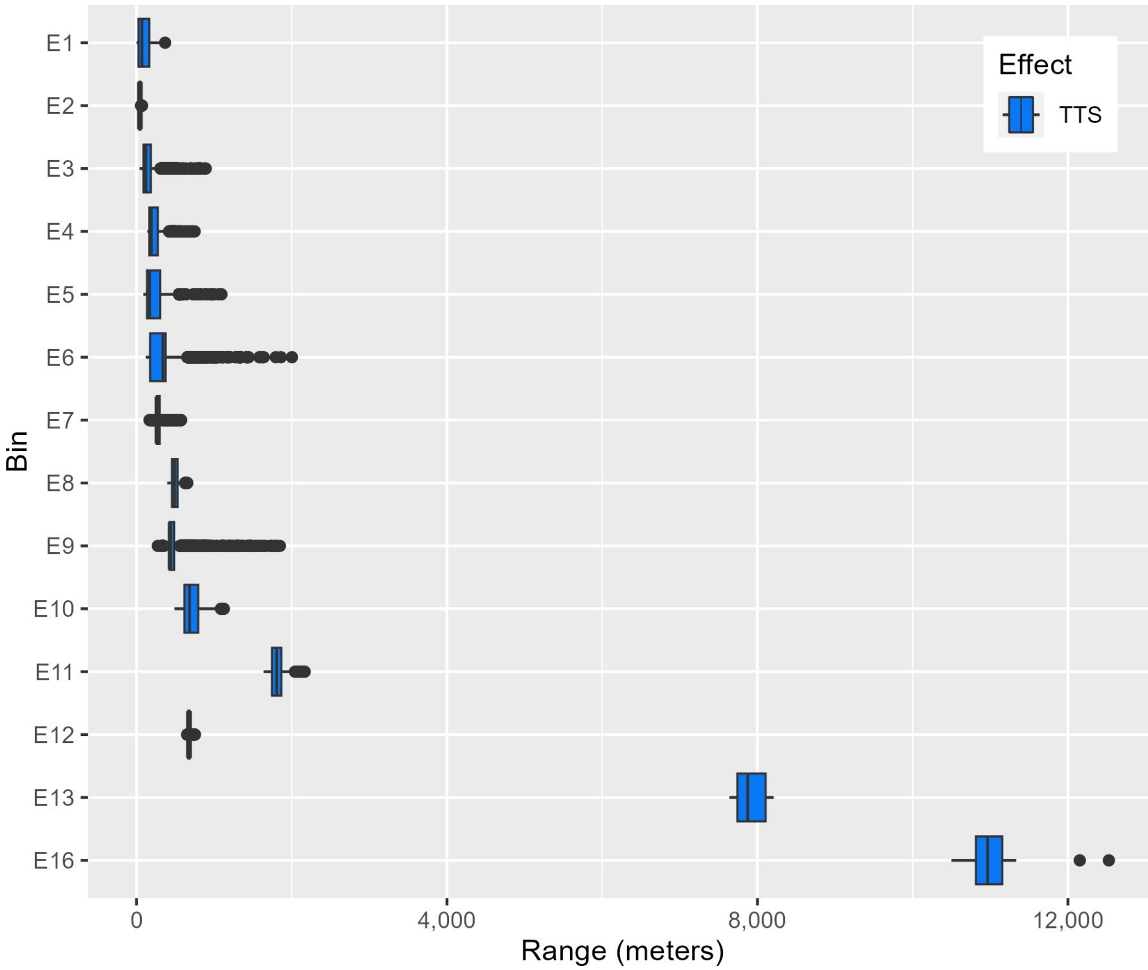

Figure 4.4-3: Explosive Ranges to Temporary Threshold Shift for Fishes with a Swim Bladder

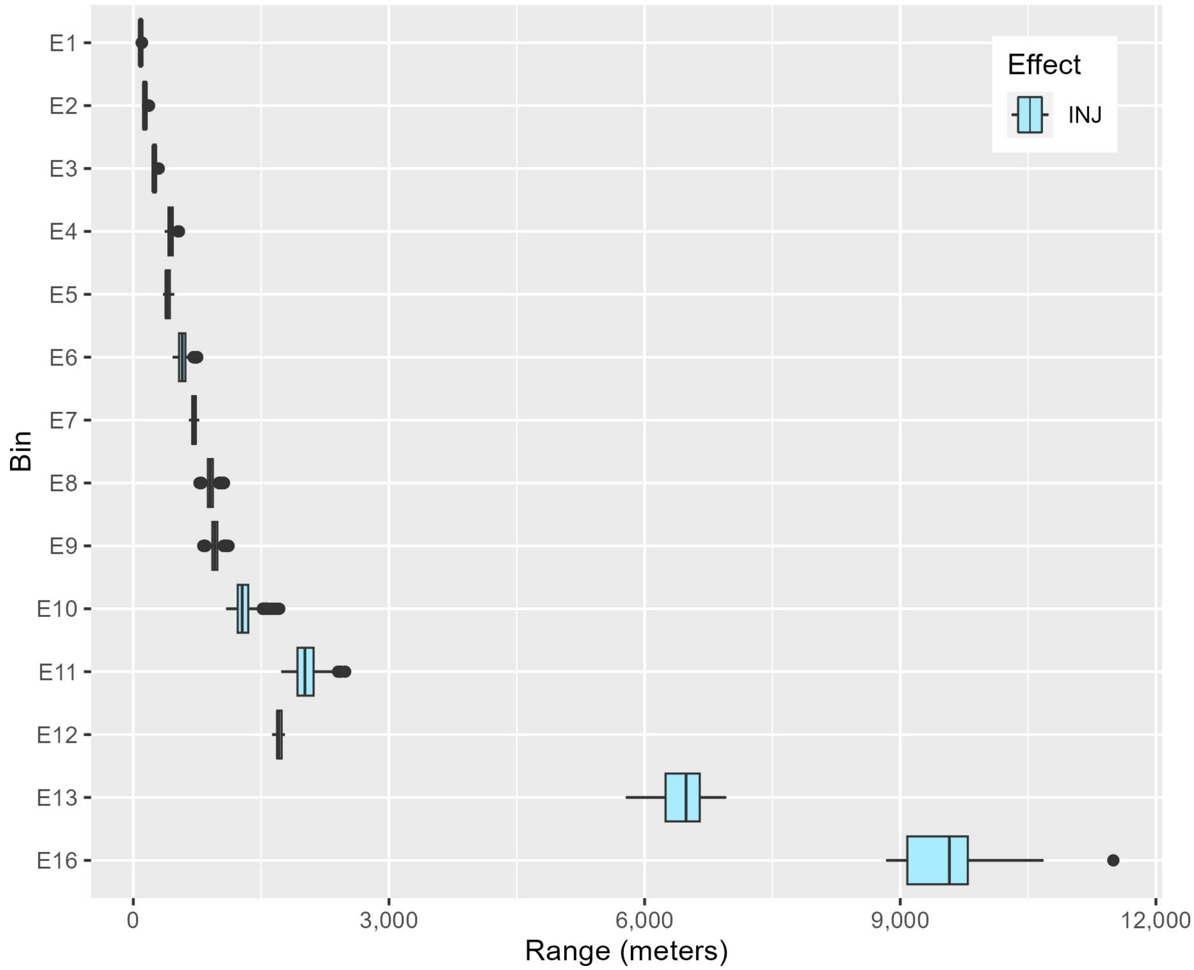

Figure 4.4-4: Explosive Ranges to Injury for Fishes with a Swim Bladder

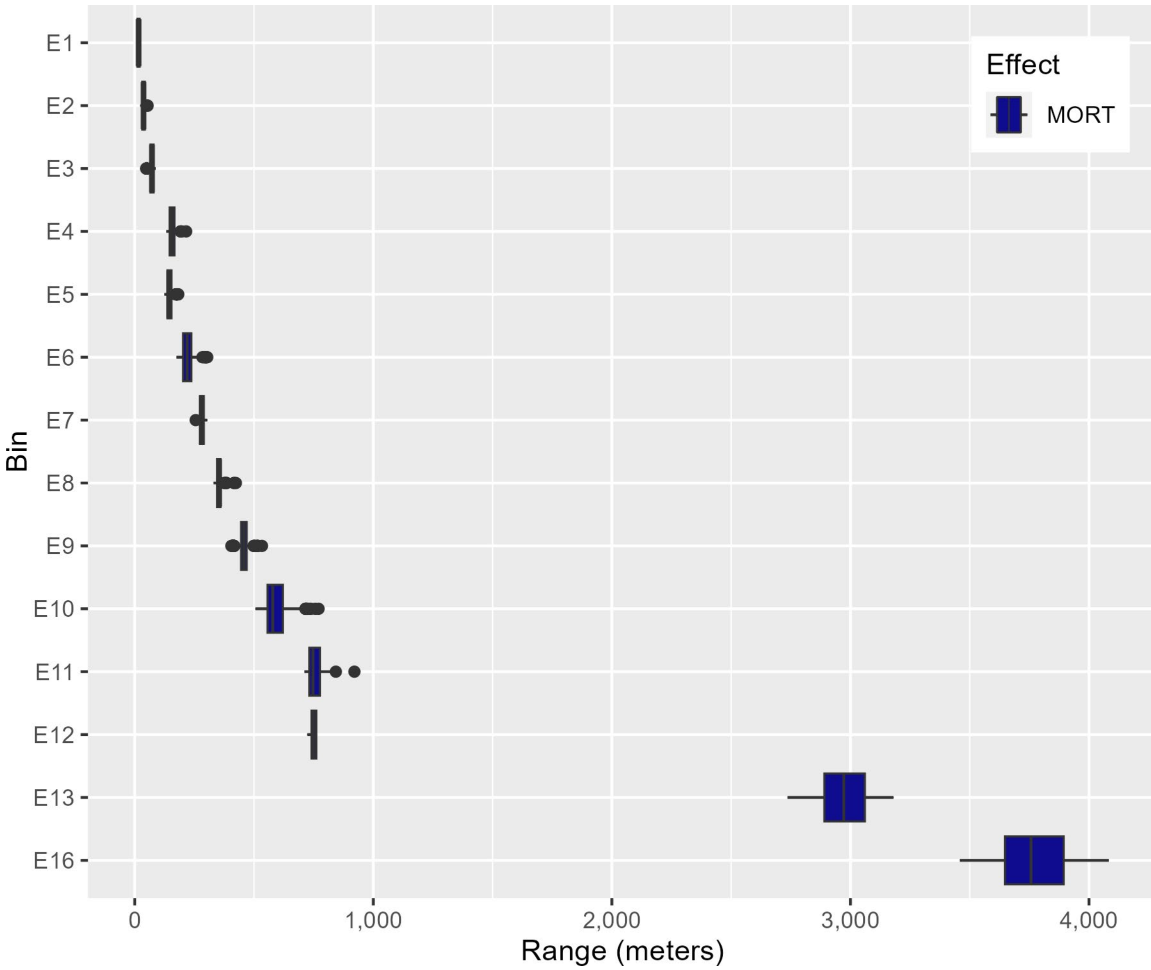

Figure 4.4-5: Explosive Ranges to Mortality for Fishes with a Swim Bladder

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Appendix E.1 In-Air Acoustic Effects on Pinnipeds from Weapons Firing Noise

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APPENDIX E.1 In-Air Acoustic Effects on Pinnipeds from Weapons Firing Noise

This appendix presents the analysis of weapons firing at San Nicolas Island (SNI) and Pacific Missile Range Facility (PMRF) resulting in estimated in-air acoustic effects on pinnipeds. The acoustic stressors predicted to result in effects are (1) noise associated with missile and aerial target launches occurring on land-based sites at SNI and PMRF, and (2) noise associated with artillery firing at PMRF from land-based sites.

E.1.1 Predicting Effects from Missile and Aerial Target Launches at SNI

SNI is Navy owned and located within the PMSR approximately 60 miles southwest of Point Mugu, California. Due to its remote location, SNI is ideally suited as a site to launch missiles and aerial targets used for military training and testing. Typical airborne target systems include small jet-powered drones, supersonic missiles and targets, and full-scale unmanned fighter aircraft, which can be flown via remote control from the ground. Airborne targets can be launched from aircraft, surface launch sites at SNI, or from a support vessel. However, only launches from SNI would have the potential to affect pinnipeds hauled out on SNI during a launch event.

The number of annual target and missile launches from SNI would be consistent with past and ongoing activities (i.e., approximately 40 events per year), and the analysis of effects would also remain consistent with previously presented analyses (National Oceanic and Atmospheric Administration, 2022; U.S. Department of the Navy, 2022b).

Noises with sudden onset or high amplitude relative to the ambient noise level may elicit a behavioral response from pinnipeds resting on shore; however, noise from launches is typically detectable by pinnipeds on beaches at the west end of SNI for no more than a few seconds per launch (Holst & Greene Jr., 2005; Holst & Greene Jr., 2008). Pinniped reactions to launches from SNI are well documented (Burke, 2017; Holst et al., 2011; Holst & Greene Jr., 2005; Holst & Greene Jr., 2008; Holst & Greene Jr., 2010; U.S. Department of the Navy, 2020a, 2022a, 2023; Ugoretz, 2014, 2015, 2016; Ugoretz & Greene Jr., 2012), and the results show that responses vary among species and scenarios. California sea lions, northern elephant seals, and harbor seals, the three species commonly hauled out on SNI, generally tolerate high sound levels without reacting strongly, whereas some individuals may react strongly when sound levels are lower. Responses from aerial target launches have ranged from momentary startle reactions to animals fleeing into the water or otherwise away from their resting sites. Of the three species on SNI, northern elephant seals have demonstrated a very high tolerance of acoustic disturbances (Holst & Greene Jr., 2008) and were removed from the list of target species for monitoring on SNI in 2010 (75 Federal Register 71672). In contrast, harbor seals are more easily disturbed. Regardless, most pinnipeds exhibit no more than short-term alert or startle responses (Holst et al., 2011; Holst & Greene Jr., 2005; Holst & Greene Jr., 2008). Displacement from a pre-disturbance location is typically short in duration (5–15 minutes); although some harbor seals that leave their haulout site and move into the water may not return until the following low tide, when the haulout site is again accessible.

A more detailed analysis of the environmental effects of launches from SNI was prepared by NMFS in 2014 (National Marine Fisheries Service, 2014). The resulting environmental assessment and Finding of

No Significant Impact concluded that the effect of launches from SNI is related to the sound produced by the launch vehicles, and this sound would not result in substantial effects on marine mammals or to their role in the ecosystem. Launch vehicle sound might result in short-term behavioral effects, but no long-term displacement, TTS, or AINJ effects on hauled-out pinnipeds are anticipated.

E.1.2 Impacts from Missile and Aerial Vehicle Launches and Artillery Firing at PMRF

PMRF is a Navy training and testing facility located on the western side of Kauai in the Hawaii Range Complex. Similar to SNI, the land area on PMRF is used to launch missiles and aerial targets critical for military training and testing. PMRF is also used as a location for Army and Marine Corps artillery firing.

Ranges to potential auditory effects on hauled out Hawaiian monk seals at PMRF were estimated for two noise sources: a non-impulsive missile or air vehicle launch and an impulsive artillery firing event.

E.1.2.1 Criteria to Assess Auditory Impacts on Monk Seals from Terrestrial Launch Noise

This analysis applies auditory impact thresholds for Temporary Threshold Shift (TTS) and Auditory Injury (AINJ) developed for phocids in air. The development of the auditory criteria is described in the technical report *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis (Phase IV) (U.S. Department of the Navy, 2024)*. Use of the phocid in-air criteria in this analysis likely overestimates the potential effects on Hawaiian monk seals, because research by Ruscher (In Review) indicates monk seal hearing is less sensitive than other phocid species (e.g., harbor seals, ringed seals, spotted seals).

Aerial hearing thresholds for monk seals are most similar to those obtained with northern elephant seals, another species from the subfamily Monachinae for which aerial hearing thresholds are elevated relative to Phocinae (Reichmuth et al., 2013). The cause of this elevation is likely the near total occlusion of the external auditory canal in Monachinae (Ruscher et al., 2021). As this anatomical feature effectively reduces the amount of acoustic energy reaching the inner ear, it is likely that TTS onsets in Monachinae are elevated relative to Phocinae. This is supported by the finding of reduced TTS susceptibility in a harbor seal that learned to voluntarily close its auditory canal during controlled noise exposures (Kastak et al., 2005).

E.1.2.1.1 Non-Impulsive Missile or Air Vehicle Launch Noise

As described in the *Acoustic Measurements of Pacific Missile Range Facility (PMRF) Missile Launch: March 2023* technical memorandum, Sound Pressure Level (SPL) and Sound Exposure Level (SEL) were measured from a single Medium-Range Ballistic Missile Type 3 Configuration 2 (MRBM T3C2) Target Vehicle launch event at four locations on PMRF (Kim & Norman, 2023). The technical memorandum presented noise levels at the four locations where monitors were stationed and concluded that the received levels did not exceed Temporary Threshold Shift (TTS) or Auditory Injury (AINJ) thresholds based on Phase 3 criteria, which are similar to the Phase 4 criteria for phocids in air.

However, the closest recorder (ATAR 1) was approximately 1,365 feet from the launch location. This paper briefly describes the effort to use the acoustic data to estimate the size of the area surrounding the launch site that would have exceeded the Navy Phase 4 AINJ and TTS thresholds for phocids in air (PA). These distances to auditory thresholds, also referred to as ranges to effects, could be used as a tool to determine if there is overlap between launch noise that exceeds auditory thresholds and potential Hawaiian monk seal haulout locations. If the results of the analysis show that auditory effects could occur at monk seal haulout locations, then the ranges to effects could also be used to define mitigation measures or geographic mitigation areas.

As mentioned above, there were four locations where acoustic measurements were collected during the launch, ATAR 1 through ATAR 4. The unweighted SPL of the non-impulsive event at ATAR1 (the closest location) was 129.1 dB re 20 µPa (peak received level of 143.2 dB re 20 µPa). Since the recorder was stationary and TTS/AINJ thresholds were not exceeded at that location, distances to threshold levels had to be estimated using the recorded acoustic data. This was accomplished using the spherical spreading model. In an ideal setting in which sound propagates away from a point source in air without any external influence (e.g., a barrier reflecting or attenuating the sound), the sound energy radiates uniformly outward in all directions from the source in a pattern referred to as spherical spreading. For each doubling of distance from a point source, the sound level attenuates (or drops off) at a rate of 6 dB. It is important to note that the spherical spreading model used in the analysis in this paper does not account for attenuation due to meteorological conditions, physical barriers in the environment, and variations in the type or density of vegetation impeding sound propagation, all of which would affect how far the sound propagates from the source and the ranges to auditory effects.

The Navy applies weighted SEL thresholds to assess auditory impacts as well as peak pressure thresholds for impulsive sources. Unweighted peak SPL and weighted SEL thresholds for non-impulsive sources are used by regulatory agencies to estimate impacts on phocid seals. The SEL metric is based on auditory weighting functions for specific species and their hearing sensitivities. To estimate distances to weighted SEL thresholds for the monk seal, the time waveform from ATAR 1 was filtered using the audiometric weighting function for phocids in air, and a SEL was calculated using the estimated 4.7 second duration of the event (Kim & Norman, 2023). The TTS weighted non-impulsive SEL threshold for phocids in air is 134 dB re (20 µPa)^{2}s, and the AINJ weighted SEL non-impulsive threshold for phocids in air is 154 dB re (20 µPa)^{2}s. To estimate a range to effect, the time waveform was scaled until the calculated SEL matched first the AINJ threshold and then the TTS threshold. The unweighted peak SPL of the waveform was then noted, and utilizing the spherical spreading model as described above, the approximate distance to the peak SPL threshold was calculated. Using this method, the distances to the weighted SEL thresholds were estimated to be as follows:

Weighted Non-Impulsive AINJ Threshold (SEL) = 6 feet

Weighted Non-Impulsive TTS Threshold (SEL) = 620 feet

These distances centered on the launch site are shown in Figure E.1-1. The figure shows the areas around the launch site that would be exposed to sound levels at each threshold. Monk seals hauled out on the beach would not be exposed to noise from a launch that would exceed either TTS or AINJ thresholds.

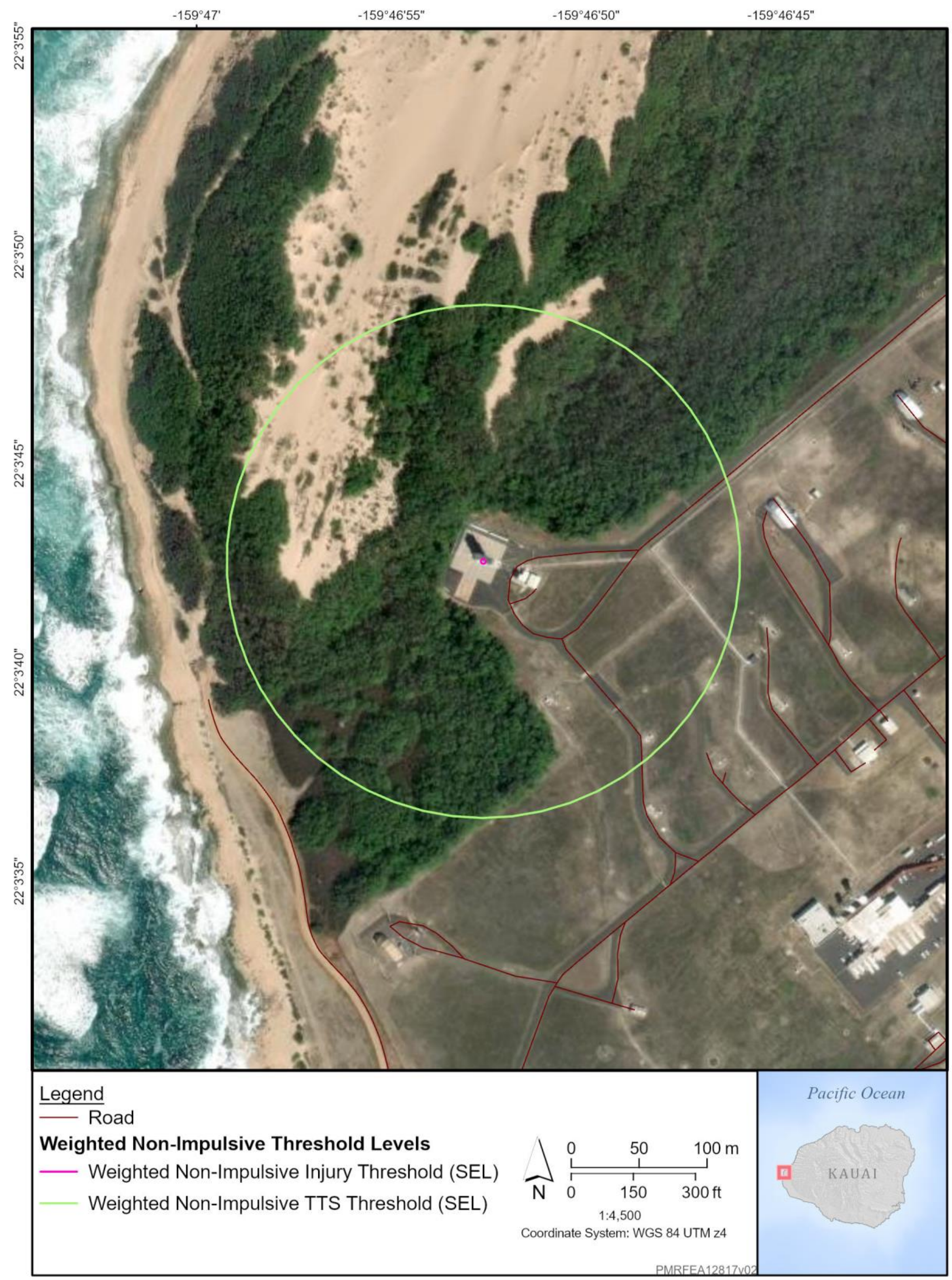

Figure E.1-1: Distances to Non-Impulsive Phocid Thresholds from Launch of T3C2 missile

The T3C2 missile represented the maximum non-impulsive sound source that would be used at PMRF and thus a "worst case" scenario for potential auditory effects to hauled out monk seals. However, a smaller rocket fired from the High Mobility Artillery Rocket System (HIMARS) would be used more regularly at PMRF. An acoustic analysis estimating ranges to auditory effects from the HIMARS is outlined below.

1. Levels of HIMARS launches at PMRF at various distances from the launch were obtained from U.S. Department of the Navy (2021). The levels are reported in overall dBA (based on the A-weighted SPL used for human noise effects measurements, see Houser et al. (2017)); thus, the frequency-specific levels necessary to apply PCA weighting for monk seals were not available.
2. The PCA and A-weighting curves were compared (Figure E.1-2). The A-weighting function discounts less acoustic energy than the PCA function across its entire frequency range, except for below 10 Hz (where both functions are near -80 dB) and above 20 kHz (where the A-weighting function is not defined). The SPL in dBA was therefore considered to be a conservative estimate of PCA-weighted SPL for the HIMARS activity.
3. The duration of the HIMARS launches was reported as 4 sec by U.S. Department of the Navy (2021), therefore 6 dB was added to the dBA values to estimate A-weighted SEL at various ranges.
4. The A-weighted source SEL at the HIMARS launch was estimated using the "dBA @ source" and "dBA @ 250 m" columns from U.S. Department of the Navy (2021), with the latter corrected assuming spherical spreading loss. These levels were 171 and 134 dB re $(20\ \mu Pa)^2$, respectively.
5. The estimated A-weighted source SELs were compared to the PCA non-impulsive TTS and AINJ criteria of 134 and 163 dB re $(20\ \mu Pa)^2$, respectively.
6. Ranges to TTS based on the "dBA @ source" and "dBA @ 250 m" values were 71 m (232 ft) and 1 m (3 ft), respectively.
7. Ranges to AINJ based on the "dBA @ source" and "dBA @ 250 m" measurements were 2.5 m (8 ft) and 0.04 m (<1 ft), respectively.
8. Based on these calculations, it is expected that no TTS or AINJ effects would occur for monk seals at ranges of greater than 61 m (200 ft) from HIMARS firing sites at PMRF comparable to that described in U.S. Department of the Navy (2021).
9. Haulout sites on beaches at PMRF are more than 200 ft from any of the HIMARS launch sites.

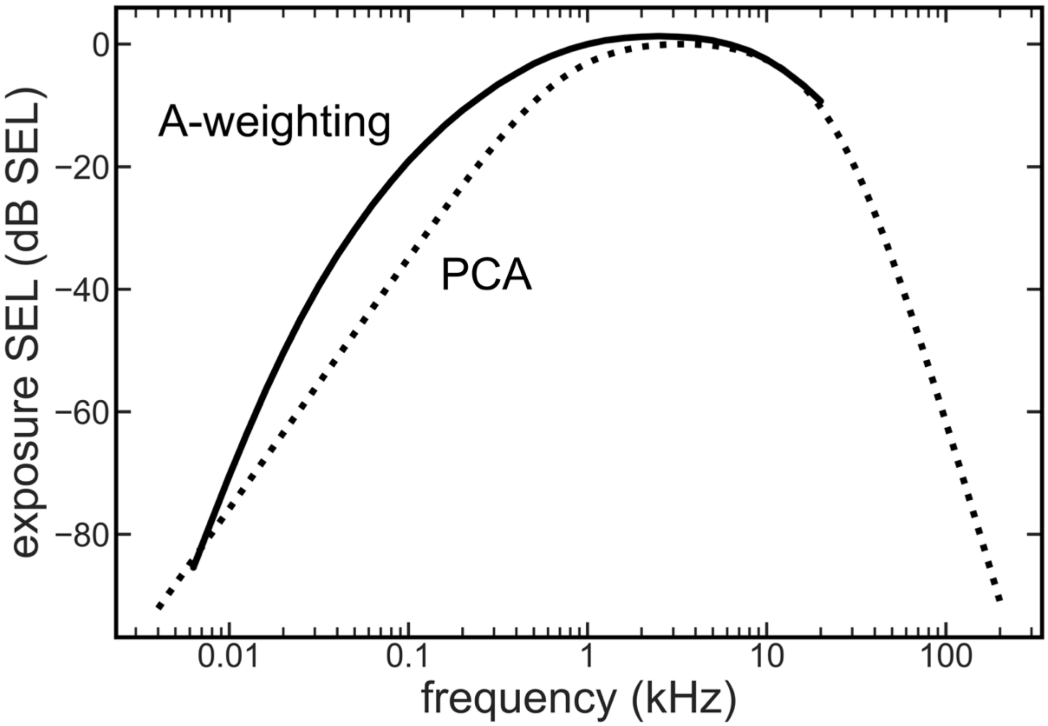

Figure E.1-2: Comparison of A-weighting and PCA weighting functions. The A-weighting curve is commonly employed by sound level meters to estimate perceived loudness by humans.

E.1.2.1.2 Impulsive Artillery Firing Noise

Artillery firing activities are proposed under the PMRF Land-Based EA, which is currently in development. The events would take place in the same locations at PMRF where the missile and launch vehicle activities would be conducted, and noise from those events have the potential to reach monk seal haulout locations.

Artillery or weapons-firing noise is considered an impulsive sound. An example of artillery that could be used is the 155mm M777 Howitzer. No acoustic measurements of artillery firing noise have been recorded at PMRF, so an estimate of ranges to auditory effects was based on published measurements. A recent study in which service members wore sensors while conducting various gun and blast activities is described in *Dynamic monitoring of service members to quantify blast exposure levels during combat training using BlackBox Biometrics Blast Gauges: explosive breaching, shoulder-fired weapons, artillery, mortars, and 0.50 caliber gun*s (Wiri et al., 2023). The analysis presented here is based on overpressure measurements reported in this study from firing a 155mm M777 Howitzer. Median and maximum peak overpressure were measured at 17 kPa (178.6 dB re 20 µPa) and 44 kPa (186.8 dB re 20 µPa), respectively. The average distance of personnel wearing sensors from the firing position is approximated to be 6 feet based on diagrams presented in the study.

Using the spherical spreading model and the maximum overpressure recorded, the distance to an approximate received level of 162 dB re 20 µPa (the Phase 4 impulsive peak SPL unweighted AINJ threshold for phocids in air) would be approximately 95 feet from the source. The impulsive unweighted peak SPL threshold for TTS is 156 dB, which would be approximately 190 feet from the source.

Unweighted Impulsive AINJ Threshold (peak SPL) = 95 feet

Unweighted Impulsive TTS Threshold (peak SPL) = 190 feet

Wiri et al. (2023) only presented data in the time-domain, meaning only sound levels are noted and no frequency information is provided. Without frequency characteristics of the sound, weighting cannot be applied to the results presented in the study. Applying a weighting function would decrease the acoustic energy perceived by monk seals, and the range to TTS effects would be less than those for unweighted values.

These distances centered on the firing site are shown in Figure E.1-3. The figure shows the areas around the firing site that would be exposed to sound levels at each threshold. Monk seals hauled out on the beach would not be exposed to noise from a launch that would exceed the AINJ or TTS thresholds.

Figure E.1-3: Distances to Impulsive Phocid Thresholds from Firing of 155mm M777 Howitzer

E.1.3 Summary of Impacts from In-Air Acoustic Stressors

SNI: Pinnipeds hauled out on the shoreline of SNI have been observed to behaviorally react to the sound of launches of targets and missiles from launch pads on the island (Naval Air Warfare Center Weapons Division, 2018; U.S. Department of the Navy, 2020b, 2022b, 2023). The estimate of the number of behavioral effects that would be expected due to in-air noise from launches was based on observations of pinnipeds over three monitoring seasons (2015–2017) divided by the number of launch events over that same time period. The Navy determined that the numbers presented in Table E.1-1 represent the number of pinnipeds expected to be hauled out at SNI based on surveys over the five-year period from 2014 to 2019 (U.S. Department of the Navy, 2020a) and the average number of effects observed per launch event (U.S. Department of the Navy, 2020b, 2022b, 2023). The estimated behavioral effects presented in Table E.1-1 are the same as those analyzed in NMFS Letter of Authorization for activities conducted on the PMSR in July 2022 (National Oceanic and Atmospheric Administration, 2022).

Table E.1-1: Behavioral Effects From In-Air Weapons Noise Due to Launches of Targets and Missiles from San Nicolas Island under Alternative 1 and Alternative 2

Species	Stock	Annual	7-Year Total
Family Otariidae (eared seals)			
California sea lion	U.S.	11,000	77,000
Family Phocidae (true seals)			
Harbor seal	California	480	3,360
Northern elephant seal	California Breeding	40	280

PMRF: From 2020 to 2023, an annual average of 215 monk seals were counted hauled out on the beach at PMRF (unpublished Navy data). The maximum number of seals observed during a single observation was five and the minimum was zero; on most observations no hauled out seals were observed. Based on the observational data, the Action Proponents estimate that weapons firing noise at PMRF would result in 215 behavioral effects annually on hauled out monk seals (Table E.1-2). The analysis conservatively assumes that (1) at least one monk seal is hauled out when a launch or firing event would occur, an assumption contradicted by the observational data, which indicates that most frequently no monk seals are hauled out on the beach; and (2) that a monk seal would be disturbed and behaviorally respond during each event. Monk seal in-air hearing is less sensitive than hearing in other phocid seals (Ruscher et al., 2021; Ruscher, In Review), suggesting that monk seals may be less likely to respond to in-air noise.

Table E.1-2: Behavioral Effects From In-Air Weapons Noise Due to Launches of Targets and Missiles and Artillery Firing at PMRF under Alternative 1 and Alternative 2

Species	Stock	Annual	7-Year Total
Family Phocidae (true seals)			
Hawaiian monk seal	NA	215	1,505

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Appendix E.2 Pile Driving Acoustic Analysis

Acoustic Effects Analysis from Pile Driving during Port Damage Repair Training Activities

December 2024

Prepared by: Bioacoustic Analysis and Applied Research Team
Naval Information Warfare Center Pacific

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APPENDIX E.2 Pile Driving Acoustic Analysis

E.2.1 Introduction

The Navy performed a quantitative analysis outside of Navy's Acoustic Effects Model to estimate the number of times that marine mammals and sea turtles could be affected by pile driving and extraction used during proposed training activities. This document summarizes the activity parameters for Port Damage Repair training, and the methodology and assumptions used in the acoustic impact analysis. Although much of the information described here is also provided in various sections and appendices of the Hawaii-California Training and Testing (HCTT) EIS/OEIS, as well as the technical report titled *Quantifying Acoustic Impacts on Marine Mammals and Sea Turtles: Methods and Analytical Approach for Phase IV Training and Testing* (U.S. Department of the Navy, 2024), the information is compiled here for easy reference and to support the conclusions made in the Navy's analysis.

The analysis considered details of the activity, sound exposure criteria, and the number and distribution of marine mammals and sea turtles. This information was then used in an 'area*density' model where the areas within each footprint (i.e., zone of influence [ZOI]) that encompass a potential effect are calculated for a given day's activities. The effects analyzed include behavioral response, TTS, and AINJ for marine mammals and sea turtles. Then, for marine mammals and sea turtles, these areas were multiplied by the density of each marine species within the nearshore environment to estimate the number of effects. Uniform density values were derived from survey data specific to the activity location. Since the same animal can be 'taken' only once every day (i.e., 24-hour reset time), the number of predicted effects from a given day were multiplied by the number of days for that activity. This generated a total estimated number of effects over the entire activity, which was then multiplied by the maximum number of times per year this activity could happen, resulting in estimated effects per species and stock in a year.

E.2.2 Activity Description

Port Damage Repair training activities are conducted by Naval Construction Groups and would involve intermittent impact and vibratory pile driving over multiple days, several times per year. Crews could work 24 hours a day for each event. Port Damage Repair training activities are made up of multiple events, each which could occur up to 12 times per year. Each training event is comprised of up to seven separate modules, each which could occur up to three iterations during a single event (for a maximum of 21 modules). Training events would last a total of 30 days, of which pile driving is only anticipated to occur for a maximum of 14 days. When training events are complete, all piles and sheets are removed via vibratory extraction or dead pull methods. The pile driving method and total number of piles to be driven are presented in
Table E.2-1.

Impact and vibratory pile driving, and removal could occur during Port Damage Repair training activities at one of three locations (Wharf Delta, Wharf 4 East or Wharf 4 South, as shown in Figure E.2-1) within the shallow waters of Port Hueneme, California. For purposes of this analysis, all acoustic modeling was conducted from a single source location approximately 50 meters from at the southeast corner of Wharf 4 East (see Figure E.2-2). This location was selected as it would result in the widest zone of influence from sound produced by in-water pile driving. Note, some training modules are only anticipated to occur at Wharf Delta, which would result in an overestimation of potential impacts by modeling at Wharf 4 East. Furthermore, acoustic modeling was limited to the footprint of the harbor as most activities would occur along the quay wall at Wharf 4 or in the enclosed area at Wharf Delta, reducing the potential for sound from pile driving to travel outside the mouth of the harbor. Although some coastal species passing near the entrance of the port (e.g., coastal bottlenose dolphins or gray whales) may detect sound from pile driving activities, behavioral responses from these exposures are not expected to rise to the level of take under military readiness.

Table E.2-1: Total Number and Type of Piles Quantitatively Analyzed under Port Damage Repair Training Activities

Pile Size and Type	Number of Piles per Module	Number of Piles per Training Event[1]	Alternative 1		Alternative 2	
			Annual[2]	7-Year	Annual[2]	7-Year
Impact (install only)						
12 to 20-inch Timber Round Piles	10 (up to 10 install, 0 remove)	30	360	2,520	360	2,520
12 to 20-inch Steel H-Piles	4 (up to 4 install, 0 remove)	12	144	1,008	144	1,008
12 to 20-inch Steel, Timber, or Composite Round Piles	10 (up to 10 install, 0 remove)	30	360	2,520	360	2,520
		Totals	***864***	***6,048***	***864***	***6,048***
Vibratory (install and/or remove)						
12 to 20-inch Timber Round Piles	10 (0 install, 10 remove)	30	360	2,520	360	2,520
12 to 20-inch Steel H-Piles	4 (0 install, 4 remove)	12	144	1,008	144	1,008
12 to 20-inch Steel, Timber or Composite Round Piles[3]	40 (15 install, 25 remove)	120	1,440	10,080	1440	10,080
27.5 or 18-inch Steel or FRP Z-shape	64 (32 install, 32 remove)	192	2,304	16,128	2,304	16,128
		Totals	***4,248***	***29,736***	***4,248***	***29,736***

[1] The Number of Piles using Impact or Vibratory Methods X 3 (to represent 3 iterations of each module within a given training event).
[2] The Number of Piles per Activity X 12 (to represent 12 events per year).

[3] Includes 12 H-beam piles (6 install, 6 remove) modeled using same surrogate acoustic data as round piles composed of any material.

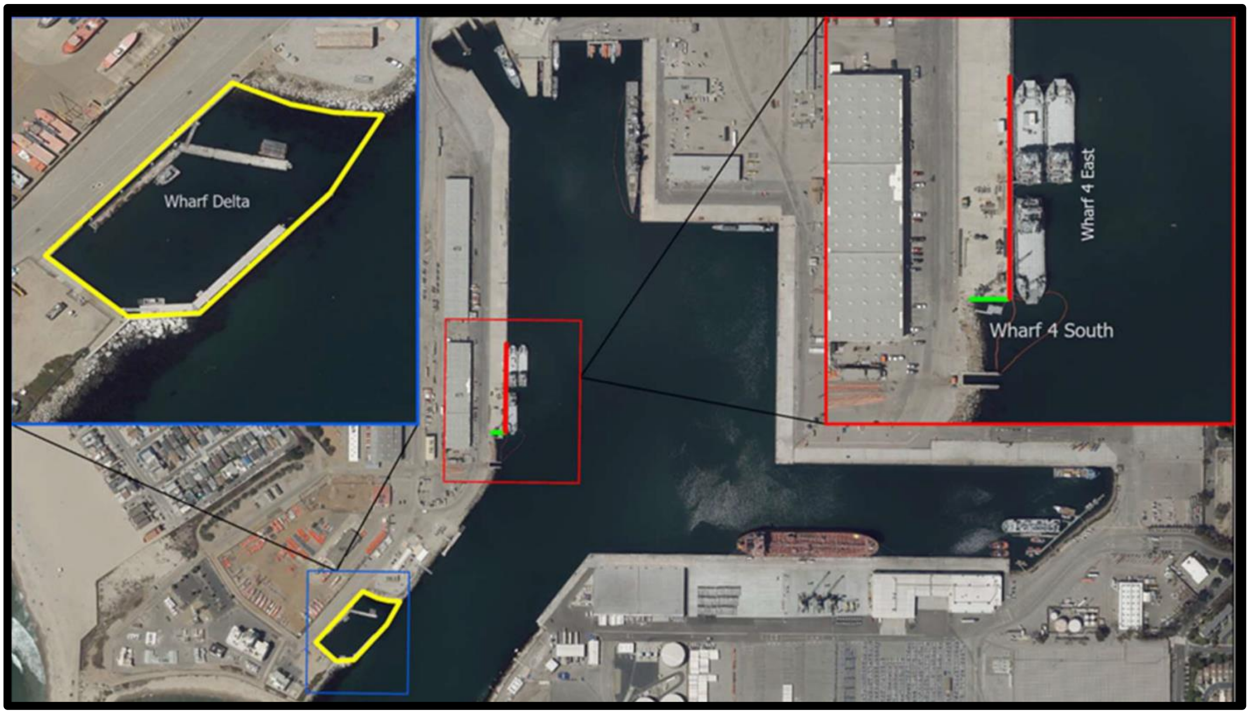

Figure E.2-1: Pile Installation/Removal Locations in Port Hueneme

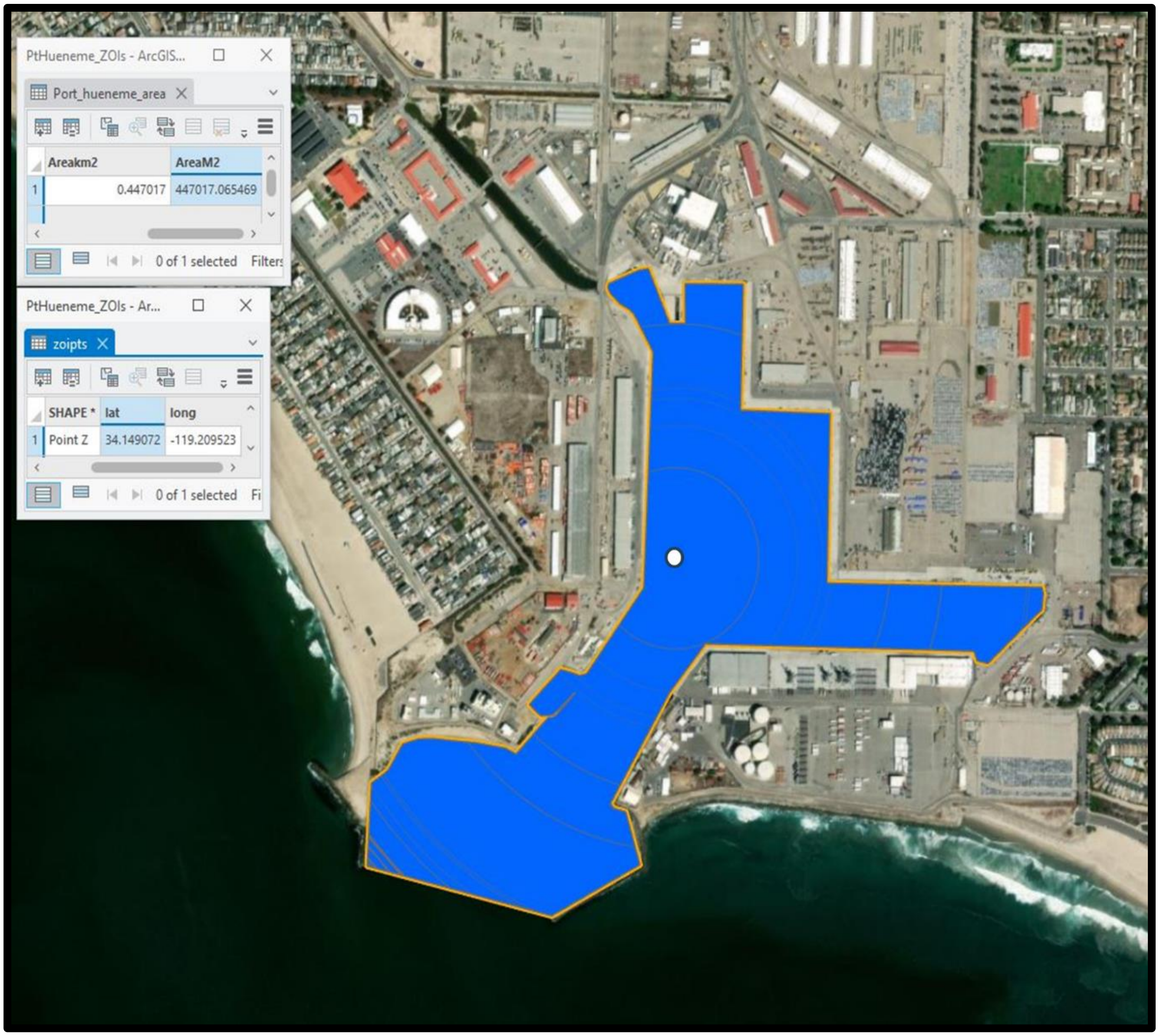

Figure E.2-2: Square Footage and Source Location for Acoustic Modeling within Port Hueneme

E.2.3 Criteria and Thresholds

A comprehensive discussion on how the criteria and thresholds for AINJ and TTS in marine mammals and sea turtles were derived is available in the Criteria and Thresholds TR. Additionally, this report includes detailed information on frequency weighting and hearing groups.

Because impact pile driving produces impulsive noise, impulsive criteria were used to assess the onset of TTS and AINJ for these sources. Vibratory pile driving and removal produces continuous, non-impulsive noise. Therefore, the non-impulsive criteria were used to assess the onset of TTS and AINJ.

Table E.2-2 shows the weighting factors that were used in this analysis for both impact and vibratory pile driving. Weighting factors were derived from the marine mammal and sea turtle weighting functions using the NMFS default frequencies based on the type of pile driving. These standard values are:

- kHz for marine mammals exposed to impact pile driving
- 2.5 kHz for marine mammals exposed to vibratory pile driving

- 0.16 kHz for sea turtles exposed to impact or vibratory pile driving

Table E.2-2: Weighting Factors Applied to Each Hearing Group for Impact and Vibratory Pile Driving (Applies to TTS and INJ Effects Only)

Marine Species Hearing Groups	Weighting Factor for Vibratory Pile Driving (cSEL)	Weighting Factor for Impact Pile Driving (cSEL)
Very Low-Frequency Cetaceans	-0.09	-0.03
Low-Frequency Cetaceans	-0.01	-0.05
High-Frequency Cetaceans	-2.32	-3.45
Very High-Frequency Cetaceans	-17.41	-21.19
Otariids (In-Water)	-3.54	-5.23
Phocids (In-Water)	-0.45	-0.80
Sirenians	-10.08	-12.86
Sea Turtles	-5.86	-5.86

cSEL: cumulative sound exposure level.

National Marine Fisheries Service (NMFS) risk criteria were applied to estimate behavioral effects from impact and vibratory pile driving. Frequency weighting was not used for behavioral response criteria for impact or vibratory pile driving and extraction.

E.2.4 Acoustic Parameters

Sound from in-water pile driving could be transmitted on direct paths through the water, be reflected at the water surface or bottom, or travel through bottom substrate. Soft substrates such as sand bottom would absorb or attenuate the sound more readily than hard substrates (rock), which may reflect the acoustic wave.

Impact pile driving would involve the use of an impact hammer with both it and the pile held in place by a crane. When the pile driving starts, the hammer part of the mechanism is raised up and allowed to fall, transferring energy to the top of the pile. The pile is thereby driven into the sediment by a repeated series of these hammer blows. Each blow results in an impulsive sound emanating from the length of the pile into the water column as well as from the bottom of the pile through the sediment. Broadband impulsive signals are produced by impact pile driving methods, with most of the acoustic energy concentrated below 1,000 hertz (Hz) (Hildebrand, 2009b).

Vibratory installation and extraction would involve the use of a vibratory hammer suspended from the crane and attached to the top of a pile. The pile is then vibrated by hydraulic motors rotating eccentric weights in the mechanism, causing a rapid vibration of the pile. The vibration and the weight of the hammer applying downward force drives the pile into the sediment. During removal, the vibration causes the sediment particles in contact with the pile to lose frictional grip on the pile. The crane slowly lifts the vibratory extraction hammer and pile until the pile is free of the sediment. In some cases, the crane may be able to lift the pile without the aid of an extraction hammer (i.e., dead pull), in which case no noise would be introduced into the water. Vibratory driving and removal create broadband, non-impulsive noise at low source levels, for a short duration with most of the energy dominated by lower frequencies (Hildebrand, 2009a).

Regardless of pile type, impact pile driving would incorporate a soft start procedure which may “warn” nearby marine species and reduce the initial noise exposure. The soft start procedure incorporates the use of three sets of three blows of the hammer at a reduced energy, with at least 30 seconds of separation between the sets. Table E.2-3 provides a summary of the sound levels selected for use in the acoustic analysis for each pile size and type to be used during Port Damage Repair activities.

Table E.2-3: Underwater Sound Levels Used in the Analysis of Pile Driving Activities

Pile Descriptions	Unattenuated Single Strike Level (dB)			Unattenuated SPL (dB rms)
	Peak SPL	RMS	SEL	
Impact (install only)				
12 to 20-inch Timber Round Piles[1]	180	170	160	-
12 to 20-inch Steel H-Piles[2]	195	180	170	-
12 to 20-inch Steel, Timber or Composite Round Piles[3]	203	189	178	-
Vibratory (install and/or remove)				
18 or 27.5-inch steel or FRP Z-piles[4]	-	-	-	159
12 to 20-inch Steel, Timber or Composite Round or H-Piles[5]	-	-	-	166

REFERENCES: (1) 14-inch round timber piles (Caltrans, 2020); (2) 14-inch steel H-beam piles (Caltrans, 2020); (3) 24-inch steel pipe piles (Illingworth and Rodkin Inc., 2007); (4) 25-inch steel sheet piles (Naval Facilities Engineering Systems Command Southwest, 2020); (5) 24-inch steel piles (Washington State Department of Transportation, 2010).

In addition to underwater noise, the installation and removal of piles would also result in airborne noise in the environment. Impact pile driving creates in-air impulsive sound up to a maximum of 114 dB re 20 μPa (unweighted) at a range of 15 meters (m) for 24-inch and 36-inch steel piles (Illingworth and Rodkin, 2017; Illingworth and Rodkin, 2015; Illingworth and Rodkin Inc., 2013). Reported sound levels for vibratory driving or extraction would be lower than that produced during impact driving (e.g., 94 dB re 20 μPa within a range of 10–15 m).

Consistent with recommendations from NMFS, transmission loss (TL) was assumed to be TL = 15 * Log10 (range). As this standard value does not account for absorption or attenuation, predicted ranges to effects and resulting ZOIs may overestimate the actual footprint of the ensonified area and therefore may overestimate the number of potential effects.

E.2.5 Ranges to Effects

Ranges to potential effects (e.g., behavioral response, TTS, and AINJ) were calculated based on the TL reported above. The functional threshold for a given effect was subtracted from the source level of a given pile (specific to the size, type, and method) to find the TL needed to reach that threshold. For TTS and AINJ the functional threshold was found by adding the weighting factor to the species-specific hearing group TTS or AINJ weighted threshold. The thresholds that were used for the behavioral response criteria were not weighted. The metric used to estimate TTS and AINJ effects was cumulative sound exposure level (cSEL), which increases with signal duration based on the number of strikes for impact pile driving (Equation 6-1) or the number of seconds for vibratory pile driving or extraction (Equation 6-2).

$$cSEL = single\ strike\ SEL + 10 * Log_{10}(\#\ strikes) \quad (6\text{-}1)$$

$$cSEL = one\ second\ SEL + 10 * Log_{10}(\#\ seconds) \quad (6\text{-}2)$$

Based on best available science regarding animal reactions to sound, selecting a reasonable accumulation period is necessary to accurately reflect the period an animal would likely be exposed to the sound. A representative duration of five minutes (300 s) was used for this accumulation period, with 60 strikes per minute per pile for piles driven using the impact method (see the AFTT and HCTT EIS/OIESs for details). Five minutes was chosen because most marine mammals and sea turtles should be able to easily move away from the expanding ZOI of TTS/AINJ within this time frame, especially considering the Navy's soft start procedures which may "warn" marine species and cause them to move away from the sound source before impact pile driving increases to full operating capacity. Alternatively, animals could avoid the zone altogether if they are outside of the immediate area upon startup. This should reduce their exposure to higher levels of individual pile strikes thereby reducing their cumulative SEL.

Once the difference between the source level and the appropriate criteria was found, the range to this TL was solved for AINJ and TTS effects using Equation 6-3 and for behavioral effects using Equation 6-4.

$$10 * 10\ \hat{}\ \left(\frac{Source\ Level\ [cSEL] - Functional\ Threshold}{spreading\ coefficient}\right) \quad (6\text{-}3)$$

$$10 * 10\ \hat{}\ \left(\frac{Source\ Level\ [dB\ RMS] - Functional\ Threshold}{spreading\ coefficient}\right) \quad (6\text{-}4)$$

This provided the single-pile range to effect for each effect category and each marine species hearing group. The ranges to effects are shown in the AFTT and HCTT EIS/OEISs.

As mentioned above, in-air noise is also produced during pile driving activities. Using a maximum source level of 114 dB re 20 µPa (unweighted) at a range of 15 meters (m) for impact pile driving, the calculated in-air ranges to all effects (AINJ, TTS and behavioral) are shorter than those estimated from in-water transmission. Because areas affected by airborne noise are smaller than the underwater impact zones, a separate in-air analysis was not conducted.

Table E.2-4 shows the predicted ranges to AINJ, TTS, and behavioral response for each marine mammal hearing group exposed to impact and vibratory pile driving.

Table E.2-4: Marine Mammal Ranges to Effects for Pile Driving

FHG	Pile Type/Size and Method	BEH	TTS	AINJ
OCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	43 m	4 m
	20" Steel H Piles using Impact Methods	215 m	201 m	20 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	685 m	69 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	3,981 m	12 m	1 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	3,981 m	36 m	2 m
PCW	20" Timber/Plastic Round Piles using Impact Methods	46 m	116 m	12 m
	20" Steel H Piles using Impact Methods	215 m	538 m	54 m
	20" Steel/Timber/Plastic Round or H Piles using Impact Methods	858 m	1,839 m	184 m
	27.5" Steel Sheet or Z-Shape Piles using Vibratory Methods	11,659 m	35 m	2 m
	20" Steel/Timber/Plastic Round Piles using Vibratory Methods	11,659 m	105 m	5 m

Note: AINJ = auditory injury, TTS = temporary threshold shift, BEH = behavior, OCW = otariids in water, PCW = phocids in water

E.2.6 Calculating the Number of Effects per Species and Stock

The ZOI for an effect is the area that encompasses the sound levels at or above a threshold for that given effect to the threshold for the next higher-order effect. For example, the ZOI for TTS is the area where sound levels meet or exceed the TTS threshold but are still below the AINJ threshold. The number of times marine mammals or sea turtles could be affected was found by multiplying these ZOIs by the density of marine species in the area.

To calculate the total area of the ZOI, one of two methods were used depending on the Study Area. For AFTT, first the single pile ZOI was needed. Since Port Damage Repair pile driving activities occur in the nearshore environment and animals would generally be seaward of this, the area of a circle (for ZOIs that do not overlap major land features) or a half-circle (for ZOIs that overlap land features) was calculated with a range (i.e., radius) to each effect category for impact and vibratory pile driving. The single pile ‘ring-shaped’ or ‘c-shaped’ ZOI for each effect was then found by subtracting the next smaller effect area (i.e., higher order effect; TTS ZOI = TTS Area - AINJ Area). For HCTT, a multi ring buffer analysis tool in GIS was used to estimate the expanding ZOI by 1-meter increments limited to the boundaries of the harbor where Port Damage Repair activities would occur. This tool created a lookup table which was then used to pull the appropriate ZOI based on the available range to effects.

As mentioned above, marine mammals and sea turtles would likely leave the immediate area of pile driving and extraction activities and may be less likely to return as activities persist. However, some ‘naïve’ animals may enter the area during the short period of time when pile driving and extraction equipment is being re-positioned between piles. Therefore, an animal “refresh rate” of 10% was selected. This means that 10% of the single pile ZOI was added for each consecutive pile within a given

24-hour period to generate the daily ZOI per effect category. These daily ZOIs were then multiplied by the number of days of pile driving and pile extraction and then summed to generate a total ZOI per effect category (i.e., behavioral response, TTS, AINJ). These total ZOIs were then multiplied by the density of marine species to produce estimates of the number of times animals of each species could be affected.

E.2.7 Port Hueneme Species Density

The species most likely to occur where Port Damage Repair activities would occur are California sea lions and harbor seals. Species specific densities are required to estimate potential effects but were not available from the NMSDD for the specific activity location. As such, survey data collected at Port Hueneme from 2020-2024 of hauled-out pinnipeds were analyzed to provide an estimated abundance estimates for each species (T. McConchie, personal communication, June 26, 2024). Sighting data suggest an average daily abundance of:

- 25.89 for California sea lions, and
- 1.52 for harbor seals

These abundances were then divided by the total area of the harbor (~0.4470 sq.km), which resulted in the following density estimates:

- 57.92 California sea lions per km^2, and
- 3.40 harbor seals per km^2.

As stated, these densities were based on counts of hauled-out pinnipeds and therefore may overestimate the total number of individuals in the water at any given time. Nevertheless, within the analysis, all individuals are assumed to remain in the water where they could be taken by in-water sound from pile driving activities. While in-air exposures are possible based on the proximity of haulout locations to pile driving training activities, this analysis assumed that any animal that would be hauled out would also enter the water at some point during pile driving. Considering that the in-water exposure area is larger than the in-air exposure area, it was not necessary to conduct a separate in-air effects analysis.

E.2.8 References

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Appendix F Acoustic and Non-Acoustic Effects Supporting Information

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APPENDIX F Acoustic and Non-Acoustic Effects Supporting Information

F.1 Biological Resource Methods

The analysis of effects on biological resources focused on the likelihood of encountering the stressor, the primary stimulus, response, and recovery of individual organisms. Where appropriate, the potential of a biological resource to overlap with a stressor was analyzed with consideration given to the specific geographic area (large marine ecosystems, open ocean areas, range complexes, Study Areas, and other training and testing areas) in which the overlap could occur. Additionally, the differential effects of training versus testing activities that introduce stressors to the resource were considered.

F.1.1 Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities

This conceptual framework describes the potential effects from exposure to acoustic and explosive activities and the accompanying short-term costs to the animal (e.g., expended energy or missed feeding opportunity). It then outlines the conditions that may lead to long-term consequences for the individual if the animal cannot fully recover from the short-term costs and how these in turn may affect the population. Within each biological resource section (e.g., marine mammals, birds, and fishes) the detailed methods to predict effects on specific taxa are derived from this conceptual framework.

An animal is considered "exposed" to a sound if the received sound level at the animal's location is above the background ambient noise level within a similar frequency band. A variety of effects may result from exposure to acoustic and explosive activities.

The categories of potential effects are shown in the box below:

- ***Injury and other non-auditory injury*** *- Injury to organs or tissues of an animal.*
- ***Hearing loss*** *- A noise-induced decrease in hearing sensitivity which can be either temporary or permanent and may be limited to a narrow frequency range of hearing.*
- ***Masking*** *- When the perception of a biologically important sound (i.e., signal) is interfered with by a second sound (i.e., noise).*
- ***Physiological stress*** *- An adaptive process that helps an animal cope with changing conditions; although, too much stress can result in physiological problems.*
- ***Behavioral response*** *- A reaction ranging from very minor and brief changes in attentional focus, changes in biologically important behaviors, and avoidance of a sound source or area, to aggression or prolonged flight.*

Figure F-1 is a flowchart that diagrams the process used to evaluate the potential effects to marine animals exposed to sound-producing activities. The shape and color of each box on the flowchart represent either a decision point in the analysis (green diamonds); specific processes such as responses, costs, or recovery (blue rectangles); external factors to consider (purple parallelograms); and final outcomes for the individual or population (orange ovals and rectangles). Each box is labeled for reference throughout the following sections. For simplicity, sound is used here to include not only sound waves but also blast waves generated from explosive sources. Box A1, the Sound-Producing Activity, is the source of this stimuli and therefore the starting point in the analysis.

The first step in predicting whether an activity is capable of affecting a marine animal is to define the stimuli experienced by the animal. The stimuli include the overall level of activity, the surrounding acoustical environment, and characteristics of the sound when it reaches the animal.

Sounds emitted from a sound-producing activity (Box A1) travel through the environment to create a spatially variable sound field. The received sound by the animal (Box A2) determines the range of possible effects. The received sound can be evaluated in several ways, including number of times the sound is experienced (repetitive exposures), total received energy, or highest sound pressure level (SPL) experienced.

Sounds that are higher than the ambient noise level and within an animal's hearing sensitivity range (Box A3) have the potential to cause effects. There can be any number of individual sound sources in a given activity, each with its own unique characteristics. For example, a Navy training exercise may involve several ships and aircraft using several types of sonar. Environmental factors such as temperature and bottom type impact how sound spreads and attenuates through the environment. Additionally, independent of the sounds, the overall level of activity and the number and movement of sound sources are important to help predict the probable reactions.

The magnitude of the responses is based on the characteristics of the acoustic stimuli and the characteristics of the animal (species, susceptibility, life history stage, size, and past experiences). Very high exposure levels close to explosives have the potential to cause injury. High-level, long-duration, or repetitive exposures may potentially cause some hearing loss. All perceived sounds may lead to behavioral responses, physiological stress, and masking. Many sounds, including sounds that are not detectable by the animal, could have no effect (Box A4).

F.1.1.1 Injury

Injury (Box B1) refers to the direct injury of tissues and organs by shock or pressure waves impinging upon or traveling through an animal's body. Marine animals are well adapted to large, but relatively slow, hydrostatic pressure changes that occur with changing depth. However, injury may result from exposure to rapid pressure changes, such that the tissues do not have time to adequately adjust.

Therefore, injury is normally limited to relatively close ranges from explosions. Injury can be mild and fully recoverable or, in some cases, lead to mortality.

Injury includes both auditory and non-auditory injury. Auditory injury is the direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and injury to the inner ear structures such as the organ of Corti and the associated hair cells.

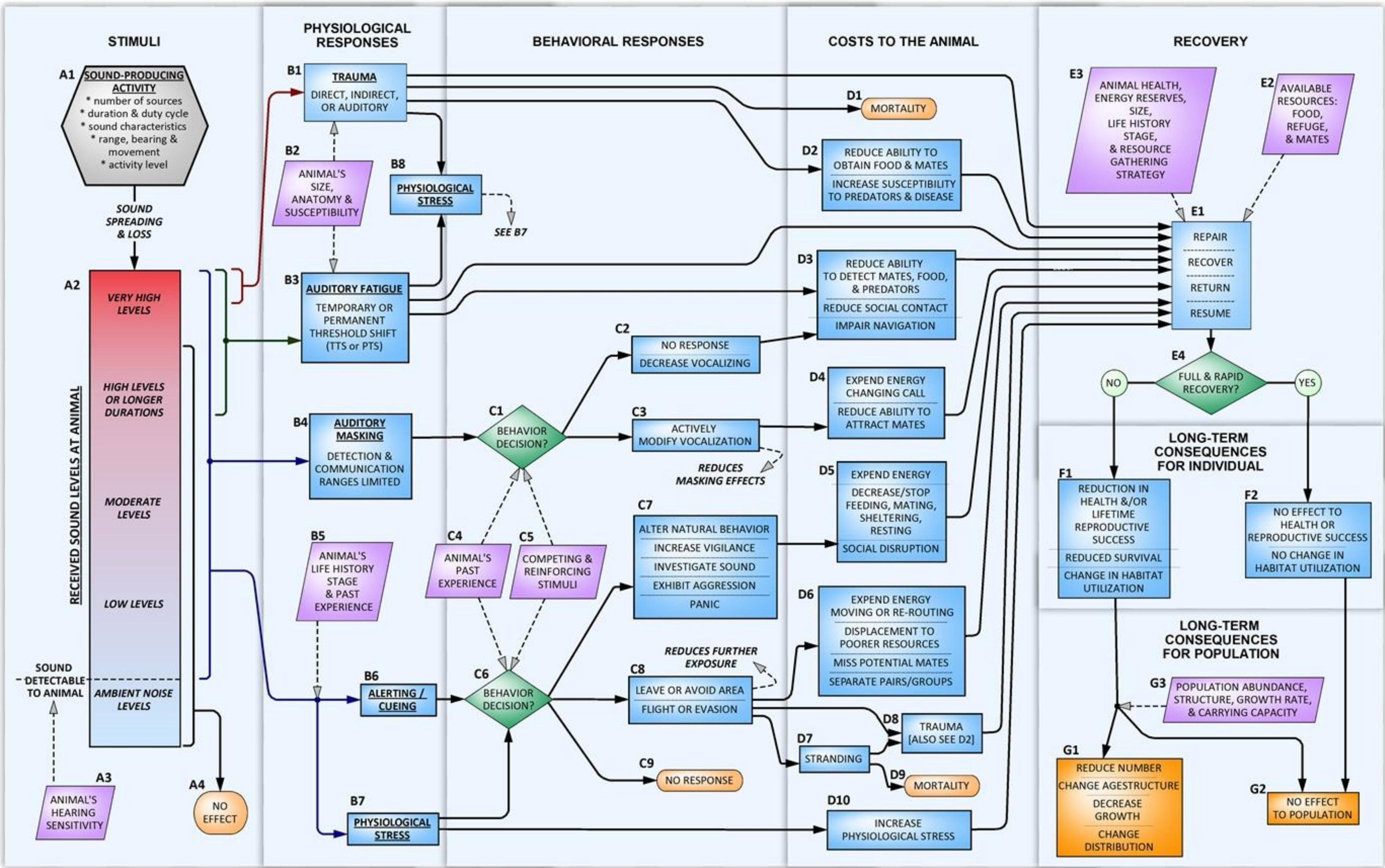


Figure F-1: Flow Chart of the Evaluation Process of Sound-Producing Activities

Auditory injury differs from auditory fatigue in that the latter involves the overstimulation of the auditory system at levels below those capable of causing direct mechanical damage. Auditory injury is always injurious but can be temporary. One of the most common consequences of auditory injury is hearing loss.

Non-auditory injury can include hemorrhaging of small blood vessels and the rupture of gas-containing tissues such as the lung, swim bladder, or gastrointestinal tract. After the ear (or other sound-sensing organs), these are usually the organs and tissues most sensitive to explosive injury. An animal's size and anatomy are important in determining its susceptibility to non-auditory injury (Box B2). Larger size indicates more tissue to protect vital organs. Therefore, larger animals should be less susceptible to injury than smaller animals. In some cases, acoustic resonance of a structure may enhance the vibrations resulting from noise exposure and result in an increased susceptibility to injury. The size, geometry, and material composition of a structure determine the frequency at which the object will resonate. Because most biological tissues are heavily damped, the increase in susceptibility from resonance is limited.

Vascular and tissue bubble formation resulting from sound exposure is a hypothesized mechanism of injury to breath-holding marine animals. Bubble formation and growth due to direct sound exposure have been hypothesized (Crum et al., 2005; Crum & Mao, 1996); however, the experimental laboratory conditions under which these phenomena were observed would not be replicated in the wild. Certain dive behaviors by breath-holding animals are predicted to result in conditions of blood nitrogen super-saturation, potentially putting an animal at risk for decompression sickness (Fahlman et al., 2014), although this phenomena has not been observed (Houser et al., 2009). In addition, animals that spend long periods of time at great depths are predicted to have super-saturated tissues that may slowly release nitrogen if the animal then spends a long time at the surface (i.e., stranding) (Houser et al., 2009).

Injury could increase the animal's physiological stress (Box B8), which feeds into the stress response (Box B7) and also increases the likelihood or severity of a behavioral response. Injury may reduce an animal's ability to secure food by reducing its mobility or the efficiency of its sensory systems, making the injured individual less attractive to potential mates, increasing an individual's chances of contracting diseases, falling prey to a predator (Box D2), or increasing an animal's overall physiological stress level (Box D10). Severe injury can lead to the death of the individual (Box D1).

Damaged tissues from mild to moderate injury may heal over time. The predicted recovery of direct injury is based on the severity of the injury, availability of resources, and characteristics of the animal. The animal may also need to recover from any potential costs due to a decrease in resource gathering efficiency and any secondary effects from predators or disease. Severe injuries can lead to reduced survivorship (longevity), elevated stress levels, and prolonged alterations in behavior that can reduce an animal's lifetime reproductive success. An animal with decreased energy stores or a lingering injury may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring produced over its lifetime.

F.1.1.2 Hearing Loss

Hearing loss, also called a noise-induced threshold shift, is possibly the most studied type of effect from sound exposures to animals. Hearing loss manifests itself as loss in hearing sensitivity across part of an animal's hearing range, which is dependent upon the specifics of the noise exposure. Hearing loss may be either permanent threshold shift (PTS), or temporary threshold shift (TTS). If the threshold shift eventually returns to zero (the animal's hearing returns to pre-exposure value), the threshold shift is a TTS. If the threshold shift does not return to zero but leaves some finite amount of threshold shift, then that remaining threshold shift is a PTS. Figure F-2 shows one hypothetical threshold shift that completely recovers, a TTS, and one that does not completely recover, leaving some PTS.

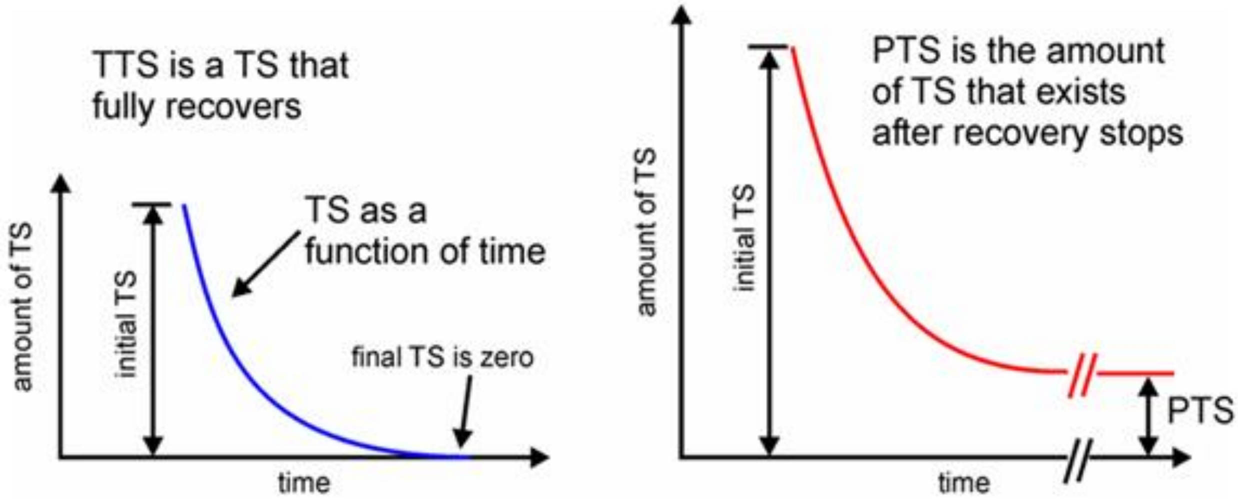


Figure F-2: Two Hypothetical Threshold Shifts

The characteristics of the received sound stimuli are used and compared to the animal's hearing sensitivity and susceptibility to noise (Box A3) to determine the potential for hearing loss. The amplitude, frequency, duration, and temporal pattern of the sound exposure are important parameters for predicting the potential for hearing loss over a specific portion of an animal's hearing range. Duration is particularly important because hearing loss increases with prolonged exposure time. Longer exposures with lower sound levels can cause more threshold shift than a shorter exposure using the same amount of energy overall. The frequency of the sound also plays an important role. Experiments show that animals are most susceptible to hearing loss (Box B3) within their most sensitive hearing range. Sounds outside of an animal's audible frequency range do not cause hearing loss.

The mechanisms responsible for hearing loss may consist of a variety of mechanical and biochemical processes in the inner ear, including physical damage or distortion of the tympanic membrane (not including tympanic membrane rupture which is considered auditory injury), physical damage or distortion of the cochlear hair cells, hair cell death, changes in cochlear blood flow, and swelling of cochlear nerve terminals (Henderson et al., 2006; Kujawa & Liberman, 2009). Although the outer hair cells are the most prominent target for fatigue effects, severe noise exposures may also result in inner hair cell death and loss of auditory nerve fibers (Henderson et al., 2006).

The relationship between TTS and PTS is complicated and poorly understood, even in humans and terrestrial mammals, where numerous studies failed to delineate a clear relationship between the two. Relatively small amounts of TTS (e.g., less than 40–50 decibels [dB] measured two minutes after exposure) will recover with no apparent permanent effects; however, terrestrial mammal studies revealed that larger amounts of threshold shift can result in permanent neural degeneration, despite the hearing thresholds returning to normal (Kujawa & Liberman, 2009). The amounts of threshold shift induced by Kujawa and Liberman (2009) were described as being "at the limits of reversibility." It is unknown whether smaller amounts of threshold shift can result in similar neural degeneration, or if effects would translate to other species such as marine animals.

Hearing loss can increase an animal's physiological stress (Box B8), which feeds into the stress response (Box B7). Hearing loss increases the likelihood or severity of a behavioral response and increase an animal's overall physiological stress level (Box D10). Hearing loss reduces the distance over which animals can communicate and detect other biologically important sounds (Box D3). Hearing loss could also be inconsequential for an animal if the frequency range affected is not critical for that animal to hear within, or the hearing loss is of such short duration (e.g., a few minutes) that there are no costs to the individual.

Small to moderate amounts of hearing loss may recover over a period of minutes to days, depending on the amount of initial threshold shift. Severe noise-induced hearing loss may not fully recover, resulting in some amount of PTS. An animal whose hearing does not recover quickly and fully could suffer a reduction in lifetime reproductive success. An animal with PTS may be less successful at mating for one or more breeding seasons, thereby decreasing the number of offspring it can produce over its lifetime.

F.1.1.3 Masking

Masking occurs if the noise from an activity interferes with an animal's ability to detect, understand, or recognize biologically relevant sounds of interest (Box B4). In this context noise refers to unwanted or unimportant sounds that mask an animal's ability to hear sounds of interest. Sounds of interest include those from conspecifics such as offspring, mates, and competitors; echolocation clicks; sounds from predators; natural, abiotic sounds that may aid in navigation; and reverberation, which can give an animal information about its location and orientation within the ocean. The probability of masking increases as the noise and sound of interest increase in similarity and the masking noise increases in level. The frequency, received level, and duty cycle of the noise determines the potential degree of auditory masking. Masking only occurs during the sound exposure.

A behavior decision (either conscious or instinctive) is made by the animal when the animal detects increased background noise, or possibly, when the animal recognizes that biologically relevant sounds are being masked (Box C1). An animal's past experiences can be important in determining the behavioral response when dealing with masking (Box C4). For example, an animal may modify its vocalizations to reduce the effects of masking noise. Other stimuli present in the environment can influence an animal's behavior decision (Box C5) such as the presence of predators, prey, or potential mates.

An animal may exhibit a passive behavioral response when coping with masking (Box C2). It may simply not respond and keep conducting its current natural behavior. An animal may also stop calling until the background noise decreases. These passive responses do not present a direct energetic cost to the animal; however, masking will continue, depending on the acoustic stimuli.

An animal may actively compensate for masking (Box C3). An animal can vocalize more loudly to make its signal heard over the masking noise. An animal may also shift the frequency of its vocalizations away from the frequency of the masking noise. This shift can actually reduce the masking effect for the animal and other animals that are listening in the area.

If masking impairs an animal's ability to hear biologically important sounds (Box D3) it could reduce an animal's ability to communicate with conspecifics or reduce opportunities to detect or attract more distant mates, gain information about their physical environment, or navigate. An animal that modifies its vocalization in response to masking could also incur a cost (Box D4). Modifying vocalizations may cost the animal energy, interfere with the behavioral function of a call, or reduce a signaler's apparent quality as a mating partner. For example, songbirds that shift their calls up an octave to compensate for increased background noise attract fewer or less-desirable mates, and many terrestrial species advertise body size and quality with low-frequency vocalizations (Slabbekoorn & Ripmeester, 2007). Masking may also lead to no measurable costs for an animal. Masking could be of short duration or intermittent such that biologically important sounds that are continuous or repeated are received by the animal between masking noise.

Masking only occurs when the sound source is operating; therefore, direct masking effects stop immediately upon cessation of the sound-producing activity. Masking could have long-term consequences for individuals if the activity was continuous or occurred frequently enough.

F.1.1.4 Physiological Stress

Marine animals naturally experience physiological stress as part of their normal life histories. The physiological response to a stressor, often termed the stress response, is an adaptive process that helps an animal cope with changing external and internal environmental conditions. Sound-producing activities have the potential to cause additional stress. However, too much of a stress response can be harmful to an animal, resulting in physiological dysfunction.

If a sound is detected (i.e., heard or sensed) by an animal, a stress response can occur (Box B7). The severity of the stress response depends on the received sound level by the animal (Box A2), the details of the sound-producing activity (Box A1), and the animal's life history stage (e.g., juvenile or adult, breeding or feeding season), and past experience with the stimuli (Box B5). An animal's life history stage is an important factor to consider when predicting whether a stress response is likely (Box B5). An animal's life history stage includes its level of physical maturity (i.e., larva, infant, juvenile, sexually mature adult) and the primary activity in which it is engaged such as mating, feeding, or rearing/caring for young. Prior experience with a stressor may be of particular importance because repeated experience with a stressor may dull the stress response via acclimation (St. Aubin & Dierauf, 2001) or increase the response via sensitization. Additionally, if an animal suffers injury or hearing loss, a physiological stress response will occur (Box B8).

The generalized stress response is characterized by a release of hormones (Reeder & Kramer, 2005) and other chemicals (e.g., stress markers) such as reactive oxidative compounds associated with noise-induced hearing loss (Henderson et al., 2006). Stress hormones include norepinephrine and epinephrine (i.e., the catecholamines), which produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipid for energy. Other stress hormones are the glucocorticoid steroid hormones cortisol and aldosterone, which are classically used as an indicator of a stress response and to characterize the magnitude of the stress response (Hennessy et al., 1979).

An acute stress response is traditionally considered part of the startle response and is hormonally characterized by the release of the catecholamines. Annoyance type reactions may be characterized by the release of either or both catecholamines and glucocorticoid hormones. Regardless of the physiological changes that make up the stress response, the stress response may contribute to an animal's decision to alter its behavior.

Elevated stress levels may occur whether or not an animal exhibits a behavioral response (Box D10). Even while undergoing a stress response, competing stimuli (e.g., food or mating opportunities) may overcome any behavioral response. Regardless of whether the animal displays a behavioral response, this tolerated stress could incur a cost to the animal. Reactive oxygen compounds produced during normal physiological processes are generally counterbalanced by enzymes and antioxidants; however, excess stress can lead to damage of lipids, proteins, and nucleic acids at the cellular level (Berlett & Stadtman, 1997; Sies, 1997; Touyz, 2004).

Frequent physiological stress responses may accumulate over time increasing an animal's chronic stress level. Each component of the stress response is variable in time, and stress hormones return to baseline levels at different rates. Elevated chronic stress levels are usually a result of a prolonged or repeated disturbance. Chronic elevations in the stress levels (e.g., cortisol levels) may produce long-term health consequences that can reduce lifetime reproductive success.

F.1.1.5 Behavioral Reactions

Behavioral responses fall into two major categories: alterations in natural behavior patterns and avoidance. These types of reactions are not mutually exclusive, and many overall reactions may be combinations of behaviors or a sequence of behaviors. Severity of behavioral reactions can vary drastically between minor and brief reorientations of the animal to investigate the sound, to severe reactions such as aggression or prolonged flight. The type and severity of the behavioral response will determine the cost to the animal. The total number of vessels and platforms involved, the size of the activity area, the distance between the animal and activity, and the duration of the activity are important considerations when predicting the initial behavioral responses.

A physiological stress response (Box B7) such as an annoyance or startle reaction, or cueing or alerting (Box B6) may cause an animal to make a behavior decision (Box C6). Any exposure that produces an injury or hearing loss is also assumed to produce a stress response (Box B7) and increase the severity or likelihood of a behavioral reaction. Both an animal's experience (Box C4) and competing and reinforcing stimuli (Box C5) can affect an animal's behavior decision. The decision can result in three general types of behavioral reactions: no response (Box C9), area avoidance (Box C8), or alteration of a natural behavior (Box C7).

An animal’s past experiences can be important in determining what behavior decision it may make when dealing with a stress response (Box C4). Habituation is the process by which an animal learns to ignore or tolerate stimuli over some period and return to a normal behavior pattern, perhaps after being exposed to the stimuli with no negative consequences. Sensitization is when an animal becomes more sensitive to a set of stimuli over time, perhaps as a result of a past, negative experience that could result in a stronger behavioral response.

Other stimuli (Box C5) present in the environment can influence an animal’s behavioral response. These stimuli may be conspecifics or predators in the area or the drive to engage in a natural behavior. Other stimuli can also reinforce the behavioral response caused by acoustic stimuli. For example, the awareness of a predator in the area coupled with the sound-producing activity may elicit a stronger reaction than the activity alone would have.

An animal may reorient, become more vigilant, or investigate if it detects a sound-producing activity (Box C7). These behaviors all require the animal to divert attention and resources, therefore slowing or stopping their presumably beneficial natural behavior. This can be a very brief diversion, or an animal may not resume its natural behaviors until after the activity has concluded. An animal may choose to leave or avoid an area where a sound-producing activity is taking place (Box C8). A more severe form of this comes in the form of flight or evasion. Avoidance of an area can help the animal avoid further effects by avoiding or reducing further exposure. An animal may also choose not to respond to a sound-producing activity (Box C9).

An animal that alters its natural behavior in response to stress or an auditory cue may slow or cease its natural behavior and instead expend energy reacting to the sound-producing activity (Box D5). Natural behaviors include feeding, breeding, sheltering, and migrating. The cost of feeding disruptions depends on the energetic requirements of individuals and the potential amount of food missed during the disruption. Alteration in breeding behavior can result in delaying reproduction. The costs of a brief interruption to migrating or sheltering are less clear.

An animal that avoids a sound-producing activity may expend additional energy moving around the area, be displaced to poorer resources, miss potential mates, or have social interactions affected (Box D6). The amount of energy expended depends on the severity of the behavioral response. Missing potential mates can result in delaying reproduction. Groups could be separated during a severe behavioral response such as flight and offspring that depend on their parents may die if they are permanently separated. Splitting up an animal group can result in a reduced group size, which can have secondary effects on individual foraging success and susceptibility to predators.

Some severe behavioral reactions can lead to stranding (Box D7) or secondary injury (Box D8). Animals that take prolonged flight, a severe avoidance reaction, may injure themselves or strand in an environment for which they are not adapted. Some injury is likely to occur to an animal that strands (Box D8). Injury can reduce the animal’s ability to secure food and mates, and increase the animal’s susceptibility to predation and disease (Box D2). An animal that strands and does not return to a hospitable environment may die (Box D9).

F.1.1.6 Long-Term Consequences

The potential long-term consequences from behavioral responses are difficult to discern. Animals displaced from their normal habitat due to an avoidance reaction may return over time and resume their natural behaviors. This is likely to depend upon the severity of the reaction and how often the activity is repeated in the area. In areas of repeated and frequent acoustic disturbance, some animals may habituate to the new baseline; conversely, species that are more sensitive may not return, or return but not resume use of the habitat in the same manner. For example, an animal may return to an area to feed but no longer rest in that area. Long-term abandonment or a change in the utilization of an area by enough individuals can change the distribution of the population. Frequent disruptions to natural behavior patterns may not allow an animal to recover between exposures, which increase the probability of causing long-term consequences to individuals.

The magnitude and type of effect and the speed and completeness of recovery (i.e., return to baseline conditions) must be considered in predicting long-term consequences to the individual animal (Box E4). The predicted recovery of the animal (Box E1) is based on the cost to the animal from any reactions, behavioral or physiological. Available resources fluctuate by season, location, and year and can play a major role in an animal’s rate of recovery (Box E2). Recovery can occur more quickly if plentiful food resources, many potential mates, or refuge or shelter is available. An animal’s health, energy reserves, size, life history stage, and resource gathering strategy affect its speed and completeness of recovery (Box E3). Animals that are in good health and have abundant energy reserves before an effect takes place will likely recover more quickly.

Animals that recover quickly and completely are unlikely to suffer reductions in their health or reproductive success, or experience changes in habitat utilization (Box F2). No population-level effects would be expected if individual animals do not suffer reductions in their lifetime reproductive success or change their habitat utilization (Box G2). Animals that do not recover quickly and fully could suffer reductions in their health and lifetime reproductive success; they could be permanently displaced or change how they use the environment; or they could die (Box F1). These long-term consequences to the individual can lead to consequences for the population (Box G1); although, population dynamics and abundance play a role in determining how many individuals would need to suffer long-term consequences before there was an effect on the population.

Long-term consequences to individuals can translate into consequences for populations dependent upon population abundance, structure, growth rate, and carry capacity. Carrying capacity describes the theoretical maximum number of animals of a particular species that the environment can support. When a population nears its carrying capacity, its growth is naturally limited by available resources and predator pressure. If one, or a few animals, in a population are removed or gather fewer resources, then other animals in the population can take advantage of the freed resources and potentially increase their health and lifetime reproductive success. Abundant populations that are near their carrying capacity (theoretical maximum abundance) that suffer consequences on a few individuals may not be affected overall. Populations that exist well below their carrying capacity may suffer greater consequences from any lasting consequences to even a few individuals. Population-level consequences can include a change in the population dynamics, a decrease in the growth rate, or a change in geographic distribution.

F.1.2 Conceptual Framework for Assessing Effects from Energy-Producing Activities

F.1.2.1 Stimuli

F.1.2.1.1 Magnitude of the Energy Stressor

Regulations do not provide threshold criteria to determine the significance of the potential effects from activities that involve the use of varying electromagnetic frequencies or lasers. Many organisms, primarily marine vertebrates, have been studied to determine their thresholds for detecting electromagnetic fields, as reviewed by Normandeau et al. (2011); however, there are no data on predictable responses to exposure above or below detection thresholds. The types of electromagnetic fields discussed are those from mine neutralization activities (magnetic influence minesweeping). High-energy and low-energy lasers were considered for analysis. Low-energy lasers (e.g., targeting systems, detection systems, laser light detection and ranging) do not pose a risk to organisms (U.S. Department of the Navy, 2010b) and, therefore, will not be discussed further. Radar was also considered for analysis and was determined not to pose a risk to biological resources.

F.1.2.1.2 Location of the Energy Stressor

Evaluation of potential energy exposure risks considered the spatial overlap of the resource occurrence and electromagnetic field and high-energy laser use. Wherever appropriate, specific geographic areas of potential effect were identified and the relative location of the resource with respect to the source was considered. For example, the greatest potential electromagnetic energy exposure is at the source, where intensity is greatest and the greatest potential for high energy laser exposure is at the ocean's surface, where high-energy laser intensity is greatest. All light energy, including laser light, entering the ocean becomes absorbed and scattered at a rate that is dependent on the frequency of the light. For most laser applications, the energy is rapidly reduced as the light penetrates the ocean.

F.1.2.1.3 Behavior of the Organism

Evaluation of potential energy exposure risk considered the behavior of the organism, especially where the organism lives and feeds (e.g., surface, water column, seafloor). The analysis for electromagnetic devices considered those species with the ability to perceive or detect electromagnetic signals. The analysis for high-energy lasers and radar particularly considered those species known to occur at or above the surface of the ocean.

F.1.2.2 Immediate Response and Costs to the Individual

Many different types of organisms (e.g., some invertebrates, fishes, turtles, birds, mammals) are sensitive to electromagnetic fields (Normandeau et al., 2011). An organism that encounters a disturbance in an electromagnetic field could respond by moving toward the source, moving away from it, or not responding at all. The types of electromagnetic devices used in the Proposed Action simulate the electromagnetic signature of a vessel passing through the water column, so the expected response would be similar to that of vessel movement. However, since there would be no actual strike potential, a physiological response would be unlikely in most cases. Recovery of an individual from encountering electromagnetic fields would be variable, but since the physiological response would likely be minimal, as reviewed by Normandeau et al. (2011), any recovery time would also be minimal.

Very little data are available to analyze potential effects on organisms from exposure to high energy lasers. For all but the highest-energy lasers, the greatest laser-related concern for marine species is damage to an organism's ability to see.

F.1.2.3 Long-Term Consequences to the Individual and Population

Long-term consequences are considered in terms of a resource's existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative effects on the resource, and the ability of the population to recover from or adapt to effects. Effects of multiple or repeated stressors on individuals are cumulative.

F.1.3 Conceptual Framework for Assessing Effects from Physical Disturbance or Strike

F.1.3.1 Stimuli

F.1.3.1.1 Size and Weight of the Objects

To determine the likelihood of a strike and the potential effects on an organism or habitat that would result from a physical strike, the size and weight of the striking object relative to the organism or habitat must be considered. For example, most small organisms and early life stages would simply be displaced by the movement generated by a large object moving through, or falling into, the water, whereas a larger organism could potentially be struck by an object since it may not be displaced by the movement of the water. The weight of the object is also a factor that would determine the severity of a strike. A strike by a heavy object would be more severe than a strike by a low-weight object (e.g., a decelerator/parachute, flare end cap, or chaff canister).

F.1.3.1.2 Location and Speed of the Objects

Evaluation of potential physical disturbance or strike risk considered the spatial overlap of the resource occurrence and potential striking objects. Analysis of effects from physical disturbance or strike stressors focuses on proposed activities that may cause an organism or habitat to be struck by an object moving through the air (e.g., aircraft), water (e.g., vessels, in-water devices, towed devices), or dropped into the water (e.g., non-explosive practice munitions and seafloor devices). The area of operation, vertical distribution, and density of these items also play central roles in the likelihood of effect. Wherever appropriate, specific geographic areas of potential effect are identified. Analysis of potential physical disturbance or strike risk also considered the speed of vessels as a measure of intensity. Some vessels move slowly, while others are capable of high speeds.

F.1.3.1.3 Buoyancy of the Objects

Evaluation of potential physical disturbance or strike risk in the ocean considered the buoyancy of targets or expended materials during operation, which will determine whether the object will be encountered at the surface, within the water column, or on the seafloor.

F.1.3.1.4 Behavior of the Organism

Evaluation of potential physical disturbance or strike risk considered where organisms occur and if they occur in the same geographic area and vertical distribution as those objects that pose strike risks.

F.1.3.2 Immediate Response and Costs to the Individual

Before being struck, some organisms would sense a pressure wave through the water and respond by remaining in place, moving away from the object, or moving toward it. An organism displaced a small distance by movements from an object falling into the water nearby would likely continue on with no response. However, others could be disturbed and may exhibit a generalized stress response. If the object actually hit the organism, direct injury in addition to stress may result. The function of the stress response in vertebrates is to rapidly raise the blood sugar level to prepare the organism to flee or fight. This generally adaptive physiological response can become a liability if the stressor persists and the organism cannot return to its baseline physiological state.

Most organisms would respond to sudden physical approach or contact by darting quickly away from the stimulus. Other species may respond by freezing in place or seeking refuge. In any case, the individual must stop whatever it was doing and divert its physiological and cognitive attention to responding to the stressor. The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the individual for other functions such as predator avoidance, reproduction, growth, and metabolism.

The ability of an organism to return to what it was doing following a physical strike (or near miss resulting in a stress response) is a function of fitness, genetic, and environmental factors. Some organisms are more tolerant of environmental or human-caused stressors than others and become acclimated more easily. Within a species, the rate at which an individual recovers from a physical disturbance or strike may be influenced by its age, sex, reproductive state, and general condition. An organism that has reacted to a sudden disturbance by swimming at burst speed would tire after some time; its blood hormone and sugar levels may not return to normal for 24 hours. During the recovery period, the organism may not be able to attain burst speeds and could be more vulnerable to predators. If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer depressed immune function and even death.

F.1.3.3 Long-Term Consequences to the Population

Long-term consequences are considered in terms of a resource's existing population level, growth and mortality rates, other stressors on the resource from the Proposed Action, cumulative effects on the resource, and the ability of the population to recover from or adapt to effects. Effects of multiple or repeated stressors on individuals are cumulative.

F.1.4 Conceptual Framework for Assessing Effects from Entanglement

F.1.4.1 Stimuli

F.1.4.1.1 Physical Properties of the Objects

For an organism to become entangled in military expended materials, the materials must have certain properties, such as the ability to form loops and a high breaking strength. Some items could have a relatively low breaking strength on their own, but that breaking strength could be increased if multiple loops were wrapped around an entangled organism.

F.1.4.1.2 Physical Features of the Resource

The physical makeup of the organism itself is also considered when evaluating the risk of entanglement. Some species, by their size or physical features, are more susceptible to entanglement than others. For example, more rigid bodies with protruding snouts (e.g., hammerhead shark) or large, rigid fins (e.g., humpback whale) would have an increased risk of entanglement when compared to species with smoother, streamlined bodies such as lamprey or eels.

F.1.4.1.3 Location of the Objects

Evaluation of potential entanglement risk considered the spatial overlap of the resource occurrence and military expended materials. Distribution and density of expended items play a central role in the likelihood of effect. Wherever appropriate, specific geographic areas of potential effect are identified.

F.1.4.1.4 Behavior of the Organism

Evaluation of potential entanglement risk considered the general behavior of the organism, including where the organism typically occurs (e.g., surface, water column, seafloor). The analysis particularly considered those species known to become entangled in nonmilitary expended materials (e.g., “marine debris”) such as fishing lines, nets, rope, and other derelict fishing gear that often entangle marine organisms.

F.1.4.2 Immediate Response and Costs to the Individual

The potential effects of entanglement on a given organism depend on the species and size of the organism. Species that have protruding snouts, fins, or appendages are more likely to become entangled than smooth-bodied organisms. Also, items could get entangled by an organism's mouth, if caught on teeth or baleen, with the rest of the item trailing alongside the organism. Materials similar to fishing gear, which is designed to entangle an organism, would be expected to have a greater entanglement potential than other materials. An entangled organism would likely try to free itself of the entangling object and in the process may become even more entangled, possibly leading to a stress response. The net result of being entangled by an object could be disruption of the normal behavior, injury due to lacerations, and other sublethal or lethal effects.

F.1.4.3 Long-Term Consequence to the Individual and Population

Consequences of entanglement could range from an organism successfully freeing itself from the object or remaining entangled indefinitely, possibly resulting in lacerations and other sublethal or lethal effects. Stress responses or infection from lacerations could lead to latent mortality. The analysis will focus on reasonably foreseeable long-term consequences of the direct effect, particularly those that could affect the fitness of an individual. Changes in an individual’s growth, survival, annual reproductive success, or lifetime reproductive success could have population-level effects if enough individuals are affected. This population-level effect would vary among species and taxonomic groups.

F.1.5 Conceptual Framework for Assessing Effects from Ingestion

F.1.5.1 Stimuli

F.1.5.1.1 Size of the Objects

To assess the ingestion risk from military expended materials, this analysis considered the size of the object relative to the animal's ability to swallow it. Some items are too large to be ingested (e.g., non-explosive practice bombs and most targets) and effects from these items are not discussed further. However, these items may potentially break down into smaller ingestible pieces over time. Items that are of ingestible size when they are introduced into the environment are carried forward for analysis within each resource section where applicable.

F.1.5.1.2 Location of the Objects

Evaluation of potential ingestion risk considered the spatial overlap of the resource occurrence and military expended materials. The distribution and density of expended items play a central role in the likelihood of effect. Wherever appropriate, specific geographic areas of potential effect were identified.

F.1.5.1.3 Buoyancy of the Objects

Evaluation of potential ingestion risk considered the buoyancy of military expended materials to determine whether the object will be encountered within the water column (including the surface) or on the seafloor. Less buoyant materials, such as solid metal materials (e.g., projectiles or munitions fragments), sink rapidly to the seafloor. More buoyant materials include less dense items (e.g., target fragments and decelerators/parachutes) that may be caught in currents and gyres or entangled in floating kelp. These materials can remain in the water column for an indefinite period of time before sinking. However, decelerators/parachutes are weighted and would generally sink, unless that sinking is suspended, in the scenario described here.

F.1.5.1.4 Feeding Behavior

Evaluation of potential ingestion risk considered the feeding behavior of the organism, including where (e.g., surface, water column, seafloor) and how (e.g., filter feeding) the organism feeds and what it feeds on. The analysis particularly considered those species known to ingest nonfood items (e.g., plastic or metal items).

F.1.5.2 Immediate Response and Costs to the Individual

Potential effects of ingesting foreign objects on a given organism depend on the species and size of the organism. Species that normally eat spiny hard-bodied invertebrates would be expected to have tougher mouths and guts than those that normally feed on softer prey. Materials similar in size and shape to the normal diet of an organism may be more likely to be ingested without causing harm to the animal; however, some general assumptions were made. Relatively small objects with smooth edges, such as shells or small-caliber projectiles, might pass through the digestive tract without causing harm. A small sharp-edged item may cause the individual immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the individual's mouth and throat), it may block the throat or obstruct digestive processes. An object may even be enclosed by a cyst in the gut lining. The net result of ingesting large foreign objects is disruption of the normal feeding behavior, which could be sublethal or lethal.

F.1.5.3 Long-Term Consequences to the Individual and Population

The consequences of ingesting nonfood items could be nutrient deficiency, bioaccumulation, uptake of toxic chemicals, compaction, and mortality. The analysis focused on reasonably foreseeable long-term consequences of the direct effect, particularly those that could affect the fitness of an individual. Changes in an individual's growth, survival, annual reproductive success, or lifetime reproductive success could have population-level effects if enough individuals were affected. This population-level effect would vary among species and taxonomic groups.

F.1.6 Conceptual Framework for Assessing Effects from Secondary Stressors

This conceptual framework describes the potential effects to marine species exposed to stressors indirectly through effects on habitat and prey availability (e.g., sediment or water quality, and physical disturbance). Stressors from Navy training and testing activities could pose indirect effects on marine biological resources via indirect effects to habitat or to prey. These include indirect effects from (1) explosives, explosion byproducts, and unexploded munitions; (2) metals; (3) chemicals; and (4) transmission of disease and parasites. The methods used to determine secondary stressors on marine resources are presented below. Once a category of primary stressor has been analyzed to determine how a marine biological resource is affected, an analysis follows of how a secondary stressor is potentially affecting a marine resource. After the secondary stressors are identified, a determination on the significance of the secondary effect is made. The same criteria to determine the level of significance for primary effects are used for secondary stressors. In addition, it is possible for a significant primary effect to produce a beneficial indirect effect. For example, sinking exercises could generate a significant effect to the seafloor and surrounding habitats, while causing a potential beneficial secondary effect by creating hard-bottom habitat for invertebrates, producing a food source for fishes, and creating structural refuges for other biological resources.

F.1.6.1 Secondary Stressors

F.1.6.1.1 Effects on Habitat

Primary effects defined in each marine resource section were used to develop a conceptual model to predict the potential secondary stressors on each habitat or resource. This conceptual model incorporated factors such as the co-occurrence of stressors in space and time, the effects or assessment endpoints of individual stressors (e.g., habitat alteration, changes in animal behavior or physiology, injury, mortality, or changes in human use), and the duration and intensity of the effects of individual stressors. For example, a secondary stressor from a munitions strike could be habitat degradation. The primary effect or stressor is the actual strike on the habitat such as the seafloor, with the introduction of military expended materials, munitions, and fragments inducing further habitat degradation.

Secondary stressors can also induce additive effects on habitats. These types of effects are also determined by summing the individual stressors with identical and quantifiable assessment endpoints. For example, if one stressor disturbed 0.25 square nautical miles (NM^2) of benthic habitat, a second stressor disturbed 0.5 NM^2, and all other stressors did not disturb benthic habitat, then the total benthic habitat disturbed would be 0.75 NM^2. For stressors with identical but not quantifiable assessment endpoints, potential additive effects were qualitatively evaluated using available scientific knowledge and best professional judgment. Other habitat effects such as underwater detonations were assessed by size of charge (net explosive weight), charge radius, height above the seafloor, substrate types in the area, and equations linking all these factors. The analysis also considered that effects of underwater explosions vary with the bottom substrate type and that the secondary effects would also be variable among substrate types.

F.1.6.1.2 Effects on Prey Availability

Assessing the effects of secondary stressors on prey availability falls into two main areas over different temporal scales: the cost to an individual over a relatively short amount of time (short-term) and the cost to an individual or population over a longer period of time (long-term).

F.1.6.2 Immediate Response and Costs to the Individual

After a primary effect was identified, an analysis of secondary stressors on that resource was initiated. This analysis examined whether indirect effects would occur after the initial (primary) effect and at what temporal scale that secondary stressor would affect the resource (short-term or long-term). An assessment was then made as to whether the secondary stressor would affect an individual or a population. For example, an underwater explosion could affect a single resource such as a fish or multiple other species in the food web (e.g., prey species such as plankton). The analysis also took into consideration whether the primary effect affected more than an individual or single species. For example, a prey species that would be directly injured or killed by an explosive blast could draw in predators or scavengers from the surrounding waters that would feed on those organisms, and in turn could be more directly susceptible to being injured or killed by subsequent explosions. For purposes of this analysis, indirect effects on a resource did not require trophic transfer (e.g., bioaccumulation) in order to be observed. It is important to note that the terms “indirect” and “secondary” describe how the effect may occur in an organism or its ecosystem and does not imply reduced severity of environmental consequences.

F.1.6.3 Long-Term Consequences to the Individual and Population

Long-term consequences of secondary stressors on an individual or population are often difficult to determine. Once a primary effect is identified, the severity of that effect helps to determine the temporal scale at which the secondary stressor can be measured. For most marine resources, the abundance of prey species near a detonation point would be diminished for a short period (weeks to months) before being repopulated by animals from adjacent waters. In some extreme cases, recovery of the habitat or prey resources could occur over a relatively long-time frame (months to years). It is important to note that indirect effects often differ among resources, spatial, and temporal scales.

F.2 Sediments and Water Quality

F.2.1 Explosives and Explosive Byproducts

Explosives may be introduced into the seawater and sediments by the Proposed Action. The explosive fillers contained within the munitions used during training and testing activities and their degradation products can enter the environment through high-order detonations (i.e., the munition functions as intended and the vast majority of explosives are consumed), low-order detonations (i.e., the munition partially functions with only a portion of the explosives consumed), or unexploded munitions (i.e., the munition fails to detonate and explosives remain in the casing). In the case of a successful detonation, only a small or residual amount of explosives may enter the marine environment (U.S. Environmental Protection Agency, 2012). A low-order detonation would result in some residual explosives and some unconsumed explosives remaining in the munitions casing entering the water. In the case of unexploded munitions, the explosives contained in the munition would not be consumed and would remain encased within the munition as it enters the marine environment. The munitions casing may corrode or rupture over time and release explosives into the sediments and water column.

The behavior of explosives and explosives byproducts in marine environments and the extent to which those constituents of explosives have adverse effects are influenced by a number of processes, including the ease with which the explosive dissolves in a liquid such as water (solubility), the degree to which explosives are attracted to other materials in the water (e.g., clay-sized particles and organic matter, sorption), and the tendency of the explosives to evaporate (volatilization). These characteristics, in turn, influence the extent to which the material is subject to biotic (biological) and abiotic (physical and chemical) transformation and degradation (Pennington & Brannon, 2002). The solubility of various explosives is provided in Table F-1. In the table, higher values indicate greater solubility. For example, high melting explosive is virtually insoluble in water. Table salt, which dissolves easily in water, is included in the table for comparison.

Table F-1: Water Solubility of Common Explosives and Explosive Degradation Products

Compound	Water Solubility[1] (mg/L at 20 ˚C)
Table salt (sodium chloride)[2]	357,000
Ammonium perchlorate (O)	249,000
Picric acid (E)	12,820
Nitrobenzene (D)	1,900
Dinitrobenzene (E)	500
Trinitrobenzene (E)	335
Dinitrotoluene (D)	160
TNT (E)	130
Tetryl (E)	51
Pentaerythritoltetranitrate (E)	43
Royal Demolition Explosive (E)	38
High Melting Explosive (E)	7

Source: (U.S. Department of the Navy, 2008a)
[1] Units are milligrams per liter at 20 degrees Celsius
[2]Table salt is not an explosive degradation product
Notes: D = explosive degradation product, E = explosive, O = oxidizer additive, TNT = trinitrotoluene

According to Walker et al. (2006), trinitrotoluene (TNT), royal demolition explosive, and high melting explosive experience rapid biological and photochemical degradation in marine systems. The authors noted that productivity in marine and estuarine systems is largely controlled by the limited availability of nitrogen. Because nitrogen is a key component of explosives, they are attractive as substrates for marine bacteria that metabolize other naturally occurring organic matter, such as polycyclic aromatic hydrocarbons. Juhasz and Naidu (2007) also noted that microbes use explosives as sources of carbon and energy.

Carr and Nipper (2003) indicated that conversion of TNT to carbon dioxide, methane, and nitrates in coastal sediments (a process referred to as "mineralization") occurred at rates that were typical for naturally occurring compounds such as phenanthrene, fluoranthene, toluene, and naphthalene. They noted that transformation of 2, 6-dinitrotoluene and picric acid by organisms in sediments is dependent on temperature and type of sediment (e.g., finer-grained). Pavlostathis and Jackson (2002) reported that the marine microalgae *Anabaena* spp. was highly efficient at the removal and metabolism of TNT in a continuous flow experiment. Nipper et al. (2002) noted that irreversible binding to sediments and biodegradation of 2, 6-dinitrotoluene, tetryl, and picric acid occurred in fine-grained sediments high in organic carbon resulting in lower concentrations of the contaminants. Cruz-Uribe et al. (2007) noted that three species of marine macroalgae metabolize TNT to 2-amino-4,6-dinitrotoluene and 4-amino-2, 6-dinitrotoluene, and speculate that "the ability of marine macroalgae to metabolize TNT is widespread, if not generic." The studies cited above indicate that TNT and its constituent products can be removed from the environment by naturally occurring biological processes in sediments, reducing sediment toxicity from these chemical contaminants.

Singh et al. (2009) indicated that biodegradation of royal demolition explosive and high melting explosive occurs with oxygen (aerobic) and without oxygen (anoxic or anaerobic), but that they were more easily degraded under anaerobic conditions. Crocker et al. (2006) indicated that the mechanisms of high melting explosive and royal demolition explosive biodegradation are similar, but that high melting explosive degrades more slowly. Singh et al. (2009) noted that royal demolition explosive and high melting explosive are biodegraded under a variety of anaerobic conditions by specific microbial species and by mixtures of such species. Zhao et al. (2004a); Zhao et al. (2004b) found that biodegradation of royal demolition explosive and high melting explosive occurs in cold marine sediments.

According to Singh et al. (2009), typical end products of the degradation of royal demolition explosive include nitrite, nitrous oxide, nitrogen, ammonia, formaldehyde, formic acid, and carbon dioxide. Crocker et al. (2006) stated that many of the primary and secondary intermediate compounds from biodegradation of royal demolition explosive and high melting explosive are unstable in water and spontaneously decompose. Thus, these explosives are degraded by a combination of biotic and abiotic reactions. Formaldehyde is subsequently metabolized to formic acid, methanol, carbon dioxide, or methane by various microorganisms (Crocker et al., 2006).

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the effects of undetonated materials and unexploded munitions on marine life.

On a localized scale, research at World War II munitions ocean disposal sites in Hawaii investigated nearby sediments, seawater, or marine life to determine if released constituents from the munitions (including explosive materials and metals) could be detected. Comparisons were made between disposal site samples and "clean" reference sites. Analysis of the samples showed no confirmed detection for explosive materials.

Investigations by Kelley et al. (2016) and Koide et al. (2016) found that intact munitions (i.e., ones that failed to detonate or non-explosive practice munitions) residing in or on soft sediments habitats provided hard substrate similar to other disposed objects or "artificial reefs" that attracted "hard substrate species," which would not have otherwise colonized the area. Sampling these species revealed that there was no bioaccumulation of munitions-related chemicals in the species (Koide et al., 2016).

On a broader scale, the island of Farallon De Medinilla (in the Mariana Islands) has been used as a target area for both explosive and non-explosive munitions since 1971. Between 1997 and 2012, the Navy conducted 14 underwater scientific surveys around the island, providing a consistent, long-term investigation of a single site where munitions have been used regularly (Smith & Marx, 2016). Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, bony fishes, and sea turtles. The investigators found no evidence over the 16-year period that the condition of the physical or biological resources had been adversely affected to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals and other marine resources were comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as that done for the Potomac River Test Range at Dahlgren, Virginia which was established in 1918 and is the nation's largest fully instrumented, over-the-water gun-firing range. Munitions tested at Dahlgren have included rounds from small caliber guns up to the Navy's largest (16 inch guns), bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013a). Results from the assessment indicate that munitions expended at Dahlgren have not contributed significant concentrations of explosive materials or explosives byproducts to the Potomac River water and sediments given those contributions are orders of magnitude less than concentrations already present in the Potomac River from natural and manmade sources (U.S. Department of the Navy, 2013f).

In summary, multiple investigations since 2007 involving survey and sampling of World War II munition dump sites off Oahu Hawaii and other locations, have found the following: (1) chemicals and degradation products from underwater munitions "do not pose a risk to human health or to fauna living in direct contact with munitions"; (2) metals measured in sediment samples next to World War II munitions are lower than naturally occurring marine levels and "do not cause a significant effect on the environment"; and (3) sediment is not a significant sink of chemicals released by degradation of the explosive components in munitions (Edwards et al., 2016).

The concentration of explosive munitions and any associated explosives byproducts at any single location in the Hawaii-California Training and Testing (HCTT) Study Area would be a small fraction of the totals that have accumulated over decades at World War II era dump sites and military ranges. Based on findings from much more intensively used locations, effects on sediments from the use of explosive munitions during training and testing activities would be negligible by comparison. As a result, explosives by-products and unexploded munitions would have no meaningful effect on sediments.

Most explosive material is consumed in an explosion, so the vast majority of explosive material entering the marine environment would be encased in munitions that failed to detonate. Failure rates for all of the munitions used in the Proposed Action are not available; however, based on the data that are available, a 5 percent munitions failure rate was applied to estimate failure rates for all munitions used in the Proposed Action. Based on the available data, low-order detonation rates are assumed to be at least an order of magnitude less than failure rates for all munitions and are not considered in the analysis. Table F-2 provides information about the rates of failure and low-order detonations for explosives and other munitions (MacDonald & Mendez, 2005).

Table F-2: Failure and Low-Order Detonation Rates of Military Munitions

Munitions	Failure Rate (Percent)	Low-Order Detonation Rate (Percent)
Guns/artillery	4.68	0.16
Hand grenades	1.78	n/a
Explosive munitions	3.37	0.09
Rockets	3.84	n/a
Submunitions	8.23	n/a

Note: n/a = not available

Most activities involving explosives and explosives byproducts would be conducted more than 3 nautical miles (NM) offshore in each range complex. Activities in these areas (3–200 NM) would be subject to federal sediment and water quality standards and guidelines.

Explosives are also used in nearshore areas (low tide line to 3 NM) specifically designated for mine countermeasure and mine neutralization activities. These activities would be subject to state sediment and water quality standards and guidelines.

For explosives byproducts, “local” refers to the water column in the vicinity of the underwater detonation. For unconsumed explosives, “local” refers to the area of potential effect from explosives in a zone of sediment about 6 feet (ft.) in diameter around the unconsumed explosive where it comes to rest on the seafloor.

F.2.2 Chemicals Other Than Explosives

Under the Proposed Action, chemicals other than explosives are associated with the following military expended materials: (1) solid-fuel propellants in missiles and rockets; (2) Otto Fuel II torpedo propellant and combustion byproducts; (3) polychlorinated biphenyls (PCBs) in target vessels used during sinking exercises; (4) other chemicals associated with munitions; and (5) chemicals that simulate chemical warfare agents, referred to as “chemical simulants.”

Hazardous air pollutants from explosives and explosives byproducts are discussed in Section 3.1 (Air Quality). Explosives and explosives byproducts are discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts). Fuels onboard manned aircraft and vessels are not reviewed, nor are fuel-loading activities, onboard operations, or maintenance activities reviewed, because normal operation and maintenance of Navy equipment is not part of the Proposed Action.

The largest chemical constituent of missiles is solid propellant. Solid propellant contains both the fuel and the oxidizer, a source of oxygen needed for combustion. An extended-range Standard Missile-2 typically contains 1,822 pounds (lb.) of solid propellant. Ammonium perchlorate is the oxidizing agent used in most modern solid-propellant formulas (Chaturvedi & Dave, 2015). It normally accounts for 50 to 85 percent of the propellant by weight. Ammonium dinitramide may also be used as an oxidizing agent. Aluminum powder as a fuel additive ranges from 5 to 22 percent by weight of solid propellant; it is added to increase missile range and payload capacity. The explosives high melting explosive (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) and royal demolition explosive (hexahydro-1,3,5-trinitro-1,3,5-triazine) may be added, although they usually comprise less than 30 percent of the propellant by weight. Many of the constituents used in propellants are also commonly used for commercial purposes but require additional processing to achieve certain properties necessary for rocket and missile propulsion. (Missile Technology Control Regime, 1996).

The U.S. Environmental Protection Agency (USEPA) issued a paper characterizing the munitions constituents accumulated at over 30 military sites around the United States and Canada where explosives and propellants have been used (U.S. Environmental Protection Agency, 2012). The sites assessed in the paper were all land-based ranges; however, the results are useful for analyzing similar activities conducted at sea. The paper noted that perchlorate was generally not detected at anti-tank ranges and that perchlorate is so soluble in water and mobile in soil that surface accumulation apparently does not occur. The paper includes a case study that estimates the amount of residual perchlorate deposited from a rocket fired at a test track. The rocket propellant contained 68 lb. of ammonium perchlorate. Samples were collected both behind the firing point and along the test track before and after the rocked was fired. No differences in perchlorate concentrations in soils were detected at any location before or after the firing, and all measurements recorded perchlorate concentrations of less than 1 microgram per kilogram. That case study concluded that 99.997 percent of perchlorate is consumed by the rocket motor (U.S. Environmental Protection Agency, 2012). Fitzpatrick et al. (2006) found similar results from an air-launched AIM-7 missile, a missile used by the Navy and similar to missiles used in the Proposed Action. These studies, and others cited in each paper, demonstrate that the motors used in rockets and missiles are highly efficient at burning propellant fuels, leaving only trace amounts often at undetectable levels in the environment.

Several torpedoes (e.g., MK-54) use Otto Fuel II as a liquid propellant. Otto Fuel II is composed of primarily three synthetic substances: Propylene glycol dinitrate and nitro-diphenylamine (76 percent), dibutyl sebacate (22 percent), and 2-nitrodiphenylamine as a stabilizer (2 percent). Propylene glycol dinitrate, which is a liquid, is the explosive component of Otto Fuel II. Dibutyl sebacate, also known as sebacic acid, is also a liquid. It is used commercially to make plastics, many of which are used for packaging food, and to enhance flavor in foods such as ice cream, candy, baked goods, and nonalcoholic drinks. The third component, 2-nitrodiphenylamine, is a solid substance used to control the combustion of the propylene glycol dinitrate (Espinoza & Wehrtmann, 2008). Combustion byproducts of Otto Fuel II include nitrous oxides, carbon monoxide, carbon dioxide, hydrogen, nitrogen, methane, ammonia, and hydrogen cyanide. During normal venting of excess pressure or upon failure of the torpedo's buoyancy bag, the following constituents are discharged: carbon dioxide, water, hydrogen, nitrogen, carbon monoxide, methane, ammonia, hydrochloric acid, hydrogen cyanide, formaldehyde, potassium chloride, ferrous oxide, potassium hydroxide, and potassium carbonate (Waters et al., 2013).

Target vessels are only used during sinking exercises, which occur infrequently. Polychlorinated biphenyls are a concern because they are present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on vessels used as targets for sinking exercises. These vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with USEPA guidelines (U.S. Environmental Protection Agency, 2014a). By rule, a sinking exercise must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep (40 Code of Federal Regulations 229.2).

The USEPA estimates that as much as 100 lb. of PCBs remain onboard sunken target vessels. The USEPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 United States Code 1341, et seq.) (U.S. Environmental Protection Agency, 2014a). Under the 2014 agreement with the USEPA, the Navy will not likely use aircraft carriers or submarines as the targets for a sinking exercise (U.S. Environmental Protection Agency, 2014a). Based on these considerations, PCBs will not be considered further.

Table F-3 lists the chemical constituents produced in the combustion of propellants and fuels, as described above, and list constituents remaining after the detonations of non-munitions, such as spotting charges and tracers. Not all of the listed chemical constituents in propellant and Otto Fuel II would be used in combination; some are substitutes that would replace another chemical in the list, depending on the type of propellant used. For example, ammonium perchlorate is the preferred oxidizer in propellant, but ammonium dinitramide could act as the oxidizer in some propellants. These constituents are in addition to the explosives contained in munitions, which were discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts).

Table F-3: Constituents in Munitions Other Than Explosives

Munitions Component	Constituent
Pyrotechnics Tracers Spotting Charges	Barium chromate Potassium perchlorate Chlorides Phosphorus Titanium compounds
Oxidizers	Lead (II) oxide
Propellant (rockets and missiles)	Ammonium perchlorate (50 to 85 percent by weight) Ammonium dinitramide Aluminum powder (5 to 21 percent by weight) High melting explosive Royal demolition explosive Hydroxyl-terminated polybutadiene Carboxyl-terminated polybutadiene Polybutadiene-acrylic acid-acrylonitrile Triphenyl bismuth Nitrate esters Nitrated plasticizers Polybutadiene-acrylic acid polymer Elastomeric polyesters Polyethers Nitrocellulose plasticized with nitroglycerine 2-nitrodiphenylamine N-methyl-4-nitroaniline Hydrazine
Otto Fuel II (torpedoes)	Propylene glycol dinitrate and Nitro-diphenylamine (76 percent by weight) dibutyl sebacate (22 percent by weight) 2-nitrodiphenylamine (2 percent by weight) Combustion products (nitrous oxides, carbon monoxide, carbon dioxide, hydrogen, nitrogen, methane, ammonia, hydrogen cyanide) Venting or buoyancy bag failure (hydrochloric acid, hydrogen cyanide, formaldehyde, potassium chloride, ferrous oxide, potassium hydroxide, and potassium carbonate)
Chemical Simulants	Navy Chemical Agent Simulant 82 glacial acetic acid triethyl phosphate sulfur hexafluoride 1,1,1,2 tetrafluoroethane 1,1-difluoroethane
Delay Elements	Barium chromate Potassium perchlorate

Munitions Component	Constituent
	Lead chromate
Fuses	Potassium perchlorate
Detonators	Fulminate of mercury Potassium perchlorate
Primers	Lead azide

The environmental fate of Otto Fuel II and its components is largely unknown. Neither the fuel mixture nor its three main components are particularly volatile or soluble in water; however, when mixed with water propylene glycol dinitrate forms a volatile mixture, making evaporation an important fate process (Espinoza & Wehrtmann, 2008). The compound 2-Nitrodiphenylamine may precipitate from water or be taken up by particulates. Dibutyl sebacate is rapidly biodegraded. Neither propylene glycol dinitrate nor 2-nitrodiphenylamine are readily biodegradable, but both of these chemicals break down when exposed to ultraviolet light (Powell et al., 1998).

Lead azide, titanium compounds, perchlorates, barium chromate, and fulminate of mercury are not natural constituents of seawater. Lead oxide is a rare, naturally occurring mineral. It is one of several lead compounds that form films on lead objects in the marine environment (Agency for Toxic Substances and Disease Registry, 2007). Metals are discussed in more detail in Section 3.2.3.2 (Metals).

Because chemical and biological warfare agents remain a security threat, the Department of Defense uses relatively harmless compounds (chemical simulants) as substitutes for chemical and biological warfare agents to test equipment intended to detect their presence. Chemical and biological agent detectors monitor for the presence of chemical and biological warfare agents and protect military personnel and civilians from the threat of exposure to these agents. The simulants trigger a response by sensors in the detection equipment without irritating or injuring personnel involved in testing detectors.

Navy Chemical Agent Simulant 82 (commonly referred to as NCAS-82), glacial acetic acid, triethyl phosphate, sulfur hexafluoride, 1,1,1,2 tetrafluoroethane (a refrigerant commonly known as R134), and 1,1-difluoroethane (a refrigerant commonly known as R-152a) are also referred to as gaseous simulants and can be released in smaller quantities in conjunction with glacial acetic acid or triethyl phosphate releases. The types of biological simulants that may be used include spore-forming bacteria, non-spore-forming bacteria, ovalbumin, bacteriophage MS2, and *Aspergillus niger*. The simulants are generally dispersed by hand at the detector or by aircraft as a fine mist or aerosol. The exposure of military personnel or the public to even small amounts of real warfare agents, such as nerve or blistering agents, or harmful biological organisms, such as anthrax, is potentially harmful and is illegal in most countries, including the United States. Furthermore, their use, including for the testing of detection equipment, is banned by international agreement.

Simulants must have one or more characteristic of a real chemical or biological agents—size, density, or aerosol behavior—to effectively mimic the agent. Simulants must also pose a minimal risk to human health and the environment to be used safely in outdoor tests. Simulants are selected using the following criteria: (1) safety to humans and the environment, and (2) the ability to trigger a response by sensors used in the detection equipment. Simulants must be relatively benign (e.g., low toxicity or effects potential) from a human health, safety, and environmental perspective. Exposure levels during testing activities should be well below concentrations associated with any adverse human health or environmental effects. The degradation products of simulants must also be harmless. Given these criteria for choosing simulants for use in testing activities, it is reasonable to conclude that simulants would have no effect on sediments and water quality in the Study Area. Simulants are not analyzed further in this section.

F.2.3 Metals

Anthropogenic sources of metals include the processing of industrial ores (e.g., iron ore), production of chemicals, fertilizers used in agriculture, the marine industry (e.g., anti-fouling anti-corrosion paints), runoff from urban and suburban sprawl, dredge spoil disposal, exhaust from automotive transportation, atmospheric deposition, and industrial emissions (Haugland et al., 2006). Metals would be introduced into nearshore and offshore marine waters and sediments by the Proposed Action. Because of the physical and chemical reactions that occur with metals in marine systems, many metals will precipitate out of seawater and settle in solid form on the seafloor where they can concentrate in sediments. Thus, metal contaminants in sediments pose a greater environmental concern than metals in the water column.

Military expended materials such as steel bomb bodies or fins, missile casings, small arms projectiles, and naval gun projectiles may contain small percentages (less than 1 percent by weight) of lead, manganese, phosphorus, sulfur, copper, nickel, tungsten, chromium, molybdenum, vanadium, boron, selenium, columbium, or titanium. Small-caliber projectiles are composed of steel with small amounts of aluminum and copper and brass casings that are 70 percent copper and 30 percent zinc. Medium- and large-caliber projectiles are composed of steel, brass, copper, tungsten, and other metals. The 20 mm cannon shells used in close-in weapons systems are composed mostly of tungsten alloy. Some projectiles have lead cores (U.S. Department of the Navy, 2008b). Torpedo guidance wire is composed of copper and cadmium coated with plastic (U.S. Department of the Navy, 2008a). Sonobuoy components include batteries and battery electrodes, lead solder, copper wire, and lead used for ballast. Thermal batteries in sonobuoys are contained in an airtight, sealed and welded stainless steel case that is 0.03-0.1 inch (in.) thick and resistant to the battery electrolytes (U.S. Department of the Navy, 2008b). Rockets are usually composed of steel and steel alloys, although composite cases made of glass, carbon, or Kevlar fiber are also used (Missile Technology Control Regime, 1996). Anchors used to moor mine shapes or other seafloor devices are often recovered but in some cases may be left on the seafloor to facilitate recovery of the device (see Section 3.0, Introduction). Metal anchors and other types of anchors (e.g., concrete blocks) with metal components are composed primarily of steel.

Non-explosive practice munitions consist of ammunition and components that contain no explosive material, and may include (1) ammunition and components that have had all explosive material removed and replaced with non-explosive material, (2) empty ammunition or components, and (3) ammunition or components that were manufactured with non-explosive material in place of all explosive material. These practice munitions vary in size from 25 to 500 lb. and are designed to simulate the characteristics of explosive munitions for training and testing activities. Some non-explosive practice munitions may also contain unburned propellant (e.g., rockets), and some may contain spotting charges or signal cartridges for locating the point of effect (e.g., smoke charges for daylight spotting or flash charges for night spotting) (U.S. Department of the Navy, 2010d). Large, non-explosive bombs—also called "practice" or "bomb dummy units"—are composed mainly of iron and steel casings filled with sand, concrete, or vermiculite. These materials are similar to those used to construct artificial reefs. Non-explosive bombs are configured to have the same weight, size, center of gravity, and ballistics as explosive bombs (U.S. Department of the Navy, 2006b). Practice bombs do not contain the explosive materials.

Decommissioned vessels used as targets for sinking exercises are selected from a list of U.S. Navy-approved vessels that have been cleaned or remediated in accordance with USEPA guidelines. By rule, vessel-sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep (40 Code of Federal Regulations part 229.2). The USEPA requires the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 United States Code 1341, et seq.).

In general, three things happen to materials that come to rest on the ocean floor: (1) they lodge in sediments where there is little or no oxygen below 4 in., (2) they remain on the ocean floor and begin to react with seawater, or (3) they remain on the ocean floor and become encrusted by marine organisms. As a result, rates of deterioration depend on the metal or metal alloy and the conditions in the immediate marine and benthic environment. If buried deep in ocean sediments, materials tend to decompose at much lower rates than when exposed to seawater (Ankley, 1996). With the exception of torpedo guidance wires and sonobuoy components, sediment burial appears to be the fate of most munitions used in marine warfare (Environmental Sciences Group, 2005b).

When metals are exposed to seawater, they begin to slowly corrode, a process that creates a layer of corroded material between the seawater and uncorroded metal. This layer of corrosion removes the metal from direct exposure to the corrosiveness of seawater, a process that further slows movement of the metals into the adjacent sediments and water column. This is particularly true of aluminum. Elevated levels of metals in sediments would be restricted to a small zone around the metal, and any release to the overlying water column would be diluted. In a similar fashion, as materials become covered by marine life, both the direct exposure of the material to seawater and the rate of corrosion decrease. Dispersal of these materials in the water column is controlled by physical mixing and diffusion, both of which tend to vary with time and location. The analysis of metals in marine systems begins with a review of studies involving metals used in military training and testing activities that may be introduced into the marine environment.

In one study, the water was sampled for lead, manganese, nickel, vanadium, and zinc at a shallow bombing range in Pamlico Sound (estuarine waters of North Carolina) immediately following a training event with non-explosive practice bombs. All water quality parameters tested, except nickel, were within the state limits. The nickel concentration was significantly higher than the state criterion, although the concentration did not differ significantly from the control site located outside the bombing range. The results suggest that bombing activities were not responsible for the elevated nickel concentrations (U.S. Department of the Navy, 2010d). A recent study conducted by the U.S. Marine Corps sampled sediments and water quality for 26 different constituents, including lead and magnesium, related to munitions at several U.S. Marine Corps water-based training ranges. These areas also were used for bombing practice. No munitions constituents were detected above screening values used at the U.S. Marine Corps water ranges (U.S. Department of the Navy, 2010d).

A study by Pait et al. (2010) of previous Navy training areas at Vieques, Puerto Rico, found generally low concentrations of metals in marine sediments. Areas in which live ammunition and loaded weapons were used ("live-fire areas") were included in the analysis. These results are relevant because the concentrations of expended munitions at Vieques are significantly greater than would be found anywhere in the HCTT Study Area. Table F-4 compares the sediment concentrations of several metals from those naval training areas with sediment screening levels established by the National Oceanic and Atmospheric Administration (Buchman, 2008).

As shown in Table F-4, average sediment concentrations of the metals evaluated, except for copper, were below both the threshold and probable effects levels (metrics similar to the effects range levels). The average copper concentration was above the threshold effect level, but below the probable effect level. For other elements: (1) the mean sediment concentration of arsenic at Vieques was 4.37 micrograms per gram (µg/g), and the highest concentration was 15.4 µg/g. Both values were below the sediment quality guidelines examined; and (2) the mean sediment concentration of manganese in sediment was 301 µg/g, and the highest concentration was 967 µg/g (Pait et al., 2010). The National Oceanic and Atmospheric Administration did not report threshold or probable effects levels for manganese.

Table F-4: Concentrations of and Screening Levels for Selected Metals in Marine Sediments, Vieques, Puerto Rico

Metal	Sediment Concentration (µg/g)			Sediment Guidelines – National Oceanic and Atmospheric Administration (µg/g)	
	Minimum	Maximum	Average	Threshold Effects Level*	Probable Effects Level*
Cadmium	0	1.92	0.15	0.68	4.21
Chromium	0	178	22.5	52.3	160
Copper	0	103	25.9	18.7	390
Lead	0	17.6	5.42	30.24	112
Mercury	N/R	0.112	0.019	130	700
Nickel	N/R	38.3	7.80	15.9	42.8
Zinc	N/R	130	34.4	124	271

Notes: N/R = not reported, µg/g = micrograms per gram

*Threshold Effects Level and Probable Effects Level are metrics similar to the effects range metrics (i.e., Effects Range Low and Effects Range Median) used to assess potential effects of contaminants on sediments. The Threshold Effects Levels is the average of the 50th percentile and the 15th percentile of a dataset and the Probable Effects Level is the average of the 50th percentile and the 85th percentile of a dataset.

The effects of lead and lithium were studied at the Canadian Forces Maritime Experimental and Test Ranges near Nanoose Bay, British Columbia, Canada (Environmental Sciences Group, 2005b). These materials are common to expendable mobile anti-submarine warfare training targets, acoustic device countermeasures, sonobuoys, and torpedoes. The study noted that lead is a naturally occurring metal in the environment and that typical concentrations of lead in seawater in the test range were between 0.01 and 0.06 parts per million (ppm), while concentration of lead in sediments was between 4 and 16 ppm. Cores of marine sediments in the test range show a steady increase in lead concentration from the bottom of the core to a depth of approximately 8 in. (20.3 centimeters [cm]). This depth corresponds to the late 1970s and early 1980s, and the lead contamination was attributed to atmospheric deposition of lead from gasoline additives. The sediment cores showed a general reduction in lead concentration to the present time, coincident with the phasing out of lead in gasoline by the mid-1980s. The study also noted that other training ranges have shown minimal effects of lead ballasts because they are usually buried deep in marine sediments where they are not biologically available. The study concluded that the lead ballasts would not adversely affect marine organisms because of the low probability of mobilization of lead.

A study by the Navy examined the effects of materials from activated seawater batteries in sonobuoys that freely dissolve in the water column (e.g., lead, silver, and copper ions), as well as nickel-plated steel housing, lead solder, copper wire, and lead shot used for sonobuoy ballast (U.S. Department of the Navy, 1993). The study concluded that constituents released by saltwater batteries as well as the decomposition of other sonobuoy components did not exceed state or federal standards, and that the reaction products are short-lived in seawater.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the effects of undetonated materials and unexploded munitions on marine life.

On a localized scale, research at World War II munitions ocean disposal sites in Hawaii investigated nearby sediments, seawater, or marine life to determine if metals could be detected. For metals, although there were localized elevated levels of arsenic and lead in several biota samples and in the sediment adjacent to the munitions, the origin of those metals could not be definitively linked to the munitions since comparison of sediment between the clean reference site and the disposal site showed relatively little difference. This was especially the case for a comparison with samples for ocean disposed dredge spoils sites (locations where material taken from the dredging of harbors on Oahu was disposed). At individual sampling sites adjacent to munitions, the concentrations of metals were not significantly higher as compared to the background at control sites and not significant in comparison to typical deep-sea marine sediments (Briggs et al., 2016). Observations and data collected also did not indicate any adverse effect to the localized ecology due to the presence of munitions degrading for over 75 years when compared to control sites. When specifically looking at marine organisms around the munitions (Kelley et al., 2016; Koide et al., 2016), the analysis indicated that in soft bottom habitats the expended items were providing hard substrate similar to other disposed objects or “artificial reefs” that attracted “hard substrate species” that would not have otherwise colonized the area and that there was no bioaccumulation of munitions-related chemicals for the species sampled (Koide et al., 2016).

On a broader scale, the island of Farallon de Medinilla (in the Mariana Islands) has been used as a target area since 1971. Between 1997 and 2012, there were 14 underwater scientific survey investigations around the island providing a long-term look at potential effects on the marine life from training and testing involving the use of munitions (Smith & Marx, 2016). Munitions use has included explosive rounds from gunfire, high explosive bombs by Navy aircraft and U.S. Air Force B-52s, in addition to the expenditure of inert rounds and non-explosive practice bombs. Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, bony fishes, and sea turtles. The investigators found no evidence over the 16-year period, that the condition of the biological resources had been adversely affected to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals, and other marine resources were comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as those performed for the Potomac River Test Range at Dahlgren, Virginia which was established in 1918 and is the nation’s largest fully instrumented, over-the-water gun-firing range. Munitions tested at Dahlgren have included rounds from small-caliber guns up to the Navy’s largest (16 in. guns), along with bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013f). Results from the assessment indicate that munitions expended at Dahlgren have not contributed significant concentrations of metals to the Potomac River and that the concentrations of metals in local sediments are orders of magnitude lower than in other areas of the Potomac River where metals are introduced from natural and other manmade sources. (U.S. Department of the Navy, 2013f).

The concentrations of metals from munitions, expended materials, and devices in any one location in the HCTT Study Area would be a small fraction of that from a World War II era munitions disposal site, or a target island used for 45 years, or a water range in a river used for almost 100 years. Based on findings from much more intensively used locations, the water quality effects from the use of munitions, expended materials, and other devices resulting from any of the proposed training and testing activities would be negligible by comparison.

F.2.4 Other Materials

Under the Proposed Action, other materials include marine markers and flares, chaff, towed and stationary targets, and miscellaneous components of other expended objects (e.g., concrete blocks used as anchors) (see Appendix I, Military Expended Materials and Direct Strike Impact Analyses, for details). These materials and components are either made mainly of non-reactive or slowly reactive materials (e.g., glass, carbon fibers, and plastics) or break down or decompose into benign byproducts (e.g., rubber, steel, iron, and concrete). Most of these objects would settle to the seafloor where they would (1) be exposed to seawater, (2) become lodged in or covered by seafloor sediments, (3) become encrusted by oxidation products such as rust, (4) dissolve slowly, or (5) be covered by marine organisms such as coral. Plastics may float or descend to the bottom, depending upon their buoyancy. Marine markers and flares are largely consumed during use.

Towed and stationary targets include floating steel drums; towed aerial targets; the trimaran; and inflatable, floating targets. The trimaran is a three-hulled boat with a 4 ft. square sail that is towed as a moving target. Large, inflatable, plastic targets can be towed or left stationary. Towed aerial targets are either (1) rectangular pieces of nylon fabric 7.5 ft. by 40 ft. that reflect radar or lasers; or (2) aluminum cylinders with a fiberglass nose cone, aluminum corner reflectors (fins), and a short plastic tail section. This second target is about 10 ft. long and weighs about 75 lb. These four targets are recovered after use, and will not be considered further.

Marine markers are pyrotechnic devices that are dropped on the water's surface during training exercises to mark a position, to support search and rescue activities, or as a bomb target. The MK 58 marker is a tin tube that weighs about 12 lb. Markers release smoke at the water surface for 40 to 60 minutes. After the pyrotechnics are consumed, the marine marker fills with seawater and sinks. Iron and aluminum constitute 35 percent of the marker by weight. To produce the lengthy smoke effect, approximately 40 percent of the marker by weight is made up of pyrotechnic materials. The propellant, explosive, and pyrotechnic constituents of MK 58 include red phosphorus (2.19 lb.) and manganese (IV) dioxide (1.40 lb.). Other constituents include magnesium powder (0.29 lb.), zinc oxide (0.12 lb.), nitrocellulose (0.000017 lb.), nitroglycerin (0.000014 lb.), and potassium nitrate (0.2 lb.). The failure rate of marine markers is approximately 5 percent (U.S. Department of the Navy, 2010c, 2010d).

Flares are used to signal, to illuminate surface areas at night in search and attack operations, and to assist with search and rescue activities. They range in weight from 5 to 14 kg. The major constituents of flares include magnesium granules and sodium nitrate. Containers are constructed of aluminum, and the entire assembly is usually consumed during flight. Flares may also contain a primer such as TNT, propellant (ammonium perchlorate), and other explosives. These materials are present in small quantities (e.g., 1.0×10^{-4} ounces [oz.] of ammonium perchlorate and 1.0×10^{-7} oz. of explosives). Small amounts of metals are used to give flares and other pyrotechnic materials bright and distinctive colors. Combustion products from flares include magnesium oxide, sodium carbonate, carbon dioxide, and water. Illuminating flares and marine markers are usually entirely consumed during use; neither is intended to be recovered. Table F-5 summarizes the components of markers and flares (U.S. Department of the Air Force, 1997).

Table F-5: Summary of Components of Marine Markers and Flares

Flare or Marker	Constituents	Composition (%)
LUU-2 Paraflare	Magnesium granules, sodium nitrate, aluminum, iron, trinitrotoluene (TNT), royal demolition explosive, ammonium perchlorate, potassium nitrate, lead, chromium, magnesium, manganese, nickel	Magnesium (54), sodium nitrate (26), aluminum (14), iron (5)
MK45 Paraflare	Aluminum, sodium nitrate, magnesium powder, nitrocellulose, TNT, copper, lead, zinc, chromium, manganese, potassium nitrate, pentaerythritol-tetranitrate, nickel, potassium perchlorate	Magnesium (45), sodium nitrate (30), aluminum (22)
MK58 Marine Marker	Aluminum, chromium, copper, lead, lead dioxide, manganese dioxide, manganese, nitroglycerin, red phosphorus, potassium nitrate, silver, zinc, zinc oxide	Iron (60), aluminum (35)

Most of the pyrotechnic components of marine markers are consumed and byproducts are released into the air. Thereafter, the aluminum and steel canister sinks to the bottom. Combustion of red phosphorus produces phosphorus oxides, which have a low toxicity to aquatic organisms. The amount of flare residue is negligible. Phosphorus contained in the marker settles to the seafloor, where it reacts with the water to produce phosphoric acid until all phosphorus is consumed by the reaction. Phosphoric acid is a variable, but normal, component of seawater (U.S. Department of the Navy, 2006a). The aluminum and iron canisters are expected to be covered by sand and sediment over time, to become encrusted by chemical corrosion, or to be covered by marine plants and animals. Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, adheres to particulates, and is transported to the bottom sediments (Monterey Bay Research Institute, 2010).

Red phosphorus, the primary pyrotechnic ingredient, constitutes 18 percent of the marine marker by weight. Toxicological studies of red phosphorus revealed an aquatic toxicity in the range of 10–100 milligrams per liter (10–100 ppm) for fish, *Daphnia* (a small aquatic crustacean), and algae (European Flame Retardants Association, 2002). Red phosphorus slowly degrades by chemical reactions to phosphine and phosphorus acids. Phosphine is very reactive and usually undergoes rapid oxidation. The final products, phosphates, are harmless (U.S. Department of the Navy, 2010c, 2010d). A study by the U.S. Department of the Air Force (1997) found that, in salt water, the degradation products of flares that do not function properly include magnesium and barium.

Chaff is an electronic countermeasure designed to confuse enemy radar by deflecting radar waves and thereby obscuring aircraft, ships, and other equipment from radar tracking sources. Chaff consists of small, thin glass fibers coated in aluminum that are light enough to remain in the air anywhere from

10 minutes to 10 hours (Farrell & Siciliano, 2007). Chaff is typically packaged in cylinders and contain a few million fibers. Chaff may be deployed from an aircraft or may be launched from a surface vessel.

The major components of the chaff glass fibers and the aluminum coating are provided in Table F-6 (Arfsten et al., 2002; Farrell & Siciliano, 2007; U.S. Department of the Air Force, 1997; U.S. Department of the Navy, 1999).

Factors influencing chaff dispersion include the altitude and location where it is released, prevailing winds, and meteorological conditions (Spargo, 2007; U.S. Department of the Navy, 1999). Doppler radar has tracked chaff plumes containing approximately 900 grams of chaff drifting 200 miles from the point of release, with the plume covering a volume of greater than 400 cubic miles (Arfsten et al., 2002). Based on the dispersion characteristics of chaff, large areas of open water would be exposed to chaff, but the chaff concentrations would be low.

Table F-6: Major Components of Chaff

Component	***Percent by Weight***
Glass Fiber	
Silicon dioxide	52–56
Alumina	12–16
Calcium oxide, magnesium oxide	16–25
Boron oxide	8–13
Sodium oxide, potassium oxide	1–4
Iron oxide	≤ 1
Aluminum Coating	
Aluminum	99.45 (min.)
Silicon and Iron	0.55 (max.)
Copper	0.05
Manganese	0.05
Zinc	0.05
Vanadium	0.05
Titanium	0.05
Others	0.05

Chaff is generally resistant to chemical weathering and likely remains in the environment for long periods. However, all the components of chaff's aluminum coating are present in seawater in trace amounts, except magnesium, which is present at 0.1 percent (Nozaki, 1997). Aluminum is the most common metal in the Earth's crust and also occurs naturally in trace amounts in the aquatic environment. Aluminum oxide and silicon dioxide are the two most common minerals in the earth's crust, and ocean waters are constantly exposed to both minerals, so the addition of small amounts of chaff would not affect water quality or sediment composition (U.S. Department of the Navy, 1999).

The dissolved concentration of aluminum in seawater ranges from 1 to 10 micrograms per liter (1 to 10 parts per billion). For comparison, the concentration in rivers is 50 micrograms per liter (50 parts per billion). In the ocean, aluminum concentrations tend to be higher on the surface, lower at middle depths, and higher again at the bottom (Li et al., 2008). Aluminum is a very reactive element and is seldom found as a free metal in nature except under highly acidic (low pH) or alkaline (high pH) conditions. It is found combined with other elements, most commonly with oxygen, silicon, and fluorine. These chemical compounds are commonly found in soil, minerals, rocks, and clays (Agency for Toxic Substances and Disease Registry, 2008; U.S. Department of the Air Force, 1994). Elemental aluminum in seawater tends to be converted by hydrolysis to aluminum hydroxide, which is relatively insoluble, and is scavenged by particulates and transported to bottom sediments (Monterey Bay Research Institute, 2010).

Because of their light weight, chaff fibers tend to float on the water surface for a short period. The fibers are quickly dispersed by waves and currents. They may be accidentally or intentionally ingested by marine life, but the fibers are non-toxic. Chemicals leached from the chaff would be diluted by the surrounding seawater, reducing the potential for chemical concentrations to reach levels that can affect sediment quality or benthic habitats.

Schiff (1977) placed chaff samples in Chesapeake Bay water for 13 days. No increases in concentration of greater than 1 ppm of aluminum, cadmium, copper, iron, or zinc were detected. Accumulation and concentration of chaff constituents is not likely under natural conditions. A U.S. Air Force study of chaff analyzed nine elements under various pH conditions: silicon, aluminum, magnesium, boron, copper, manganese, zinc, vanadium, and titanium. Only four elements were detected above the 0.02 milligrams per liter detection limit (0.02 ppm): magnesium, aluminum, zinc, and boron (U.S. Department of the Air Force, 1994). Tests of marine organisms detected no effects of chaff exposure at levels above those expected in the Study Area (Farrell & Siciliano, 2007).

F.3 Vegetation

F.3.1 Acoustic Stressors

Acoustic stressors are not applicable to vegetation and are therefore not analyzed further in this section.

F.3.2 Explosive Stressors

Single-celled algae may overlap with underwater and sea surface explosion locations. If single-celled algae are in the immediate vicinity of an explosion, only a small number of individuals are likely to be affected relative to their total population level. Additionally, the extremely fast growth rate and ubiquitous distribution of phytoplankton (Caceres et al., 2013; Levinton, 2013) suggest no meaningful effect on the resource. The low number of explosions relative to the amount of single-celled algae in the Study Area also decreases the potential for effects on these vegetation types. Based on these factors, the effect on these types of vegetation would not be detectable and they are not discussed further in this section.

Macroalgae and marine vascular plants that are attached to the seafloor may occur in locations where explosions are conducted and may be adversely affected for different reasons. Much of the attached macroalgae grows on live hard bottom that would be mostly protected in accordance with Navy mitigation measures. Visual observation mitigation occurs for explosive activities to observe for floating vegetation prior to commencing firing or an explosive detonation until the floating vegetation is clear from the mitigation zone. For mitigation, the term “floating vegetation” refers specifically to floating concentrations of detached kelp paddies and Sargassum. Many of these activities will not occur in seafloor resource mitigation areas, which would benefit vegetation that occurs there.

Attached macroalgae grow quickly and are resilient through high levels of wave action (Mach et al., 2007), which may aid in their ability to withstand underwater explosions that occur near them. Attached macroalgae typically need hard or artificial substrate in order to grow. The potential distribution of attached macroalgae can be inferred by the presence of hard or artificial substrate that occurs at depths of less than 200 m throughout the Study Area. See Section 3.2 (Sediments and Water Quality) for information regarding the distribution of hard substrate in the Study Area. If attached macroalgae are in the immediate vicinity of an explosion, only a small number of them are likely to be affected relative to their total population level. Only explosions occurring on or at shallow depth beneath the surface have the potential to affect floating macroalgae. Sea surface or underwater explosions could uproot or damage marine vascular plants if activities overlap with areas where they are rooted.

The potential for marine vascular plants (seagrass and eelgrass) to be affected by underwater and surface explosions is unlikely as seagrass and eelgrass may have very limited overlap with explosives training areas. Eelgrass are much less resilient to disturbance than marine algae; regrowth after uprooting can take up to 10 years (Dawes et al., 1997). Explosions may also temporarily increase the turbidity (sediment suspended in the water) of nearby waters, but the sediment would settle to pre-explosion conditions within a number of days. Sustained high levels of turbidity may reduce the amount of light that reaches vegetation. This scenario is not likely because seagrass and eelgrass do not overlap with explosives training areas.

F.3.3 Energy Stressors

Energy stressors are not applicable to vegetation and are therefore not analyzed further in this section.

F.3.4 Physical Disturbance and Strike Stressors

F.3.4.1 Effects from Vessels and In-Water Devices

Several different types of vessels (ships, submarines, boats, amphibious vehicles) and in-water devices (e.g., towed devices, unmanned underwater vehicles) are used during training and testing activities throughout the Study Area, as described in Chapter 2 (Description of Proposed Action and Alternatives). Vessel and in water device movements occur intermittently, are variable in duration (ranging from a few hours to a few weeks) and are dispersed throughout the Study Area. Events involving large vessels are widely spread over offshore areas, while smaller vessels are more active in nearshore areas.

The potential effects from Navy vessels and in-water devices used during training and testing activities on vegetation are based on the vertical distribution of the vegetation. Vessels and in-water devices may affect vegetation by striking or disturbing vegetation on the sea surface or seafloor (Spalding et al., 2003). In the open ocean, marine algae on the sea surface such as kelp paddies have a patchy distribution. Marine algae could be temporarily disturbed if struck by moving vessels or by the propeller action of transiting vessels. These strikes could also injure the organisms that inhabit kelp paddies or other marine algal mat, such as sea turtles, seabirds, marine invertebrates, and fish. Marine algae are resilient to winds, waves, and severe weather that could sink the mat or break it into pieces. Effects on marine algae by strikes may collapse the pneumatocysts (air sacs) that keep the mats afloat. Evidence suggests that some floating marine algae will continue to float even when up to 80 percent of the pneumatocysts are removed (Zaitsev, 1971).

Vegetation on the seafloor, such as marine vascular plants and macroalgae, may be disturbed by amphibious combat vehicles, and manned and unmanned underwater vehicles. Seagrasses are resilient to the lower levels of wave action that occur in sheltered estuarine shorelines, but are susceptible to vessel propeller scarring (Sargent et al., 1995). Seagrasses could take up to 10 years to fully regrow and recover from propeller scars (Dawes et al., 1997). Seafloor macroalgae may be present in locations where these vessels occur, but the effects would be minimal because of their resilience, distribution, and biomass. Because seafloor macroalgae in coastal areas are adapted to natural disturbances, such as storms and wave action that can exceed 32.8 ft. (10 meters [m]) per second (Mach et al., 2007), macroalgae will quickly recover from vessel movements. Macroalgae that is floating in the area may be disturbed by amphibious combat vehicle activities, but the effect would not be detectable because of the small amount of macroalgae in areas where these activities occur and will not be considered further in this section.

Towed in-water devices include towed targets that are used during activities such as missile exercises and gun exercises. These devices are operated at low speeds either on the sea surface or below it. The analysis of in-water devices will focus on towed surface targets because of the potential for effects on marine algae.

Unmanned underwater vehicles and autonomous underwater vehicles are used in training and testing activities in the Study Area. They are typically propeller driven and operate within the water column or crawl along the seafloor. The propellers of these devices are typically encased, eliminating the potential for seagrass propeller scarring. Although algae on the seafloor could be disturbed by these devices, unmanned underwater vehicles are not expected to compromise the health or condition of algae for the same reasons given for vessel disturbance.

Estimates of relative vessel and in-water device use and location for each alternative are provided in Section 3.0.3.3.4.1 (Vessels and In-Water Devices). These estimates are based on the number of activities predicted for each alternative. While these estimates provide a prediction of use, actual Navy vessel use depends upon military training requirements, deployment schedules, annual budgets, and other unpredictable factors. Testing and training concentrations are most dependent upon locations of Navy shore installations and established testing and training areas.

Because of the quantity of vessel traffic in Hawaiian nearshore waters since the 1940s (especially in waters off Oahu and within Pearl Harbor), it is thought that the existing vegetation community has shifted to dominance of species which are adapted to disturbance (Coles et al., 1997). In San Diego Bay, there are anticipated to be movements of Navy small boats, divers, and swimmers over eelgrass; otherwise, eelgrass beds are avoided to the maximum practicable extent. Because of the dredging history of San Diego Bay near the Navy ship berths, it is anticipated that any nearby vegetation is accustomed to increased sedimentation and disturbance from these activities; therefore effects from vessel movements on vegetation are expected to be similar and minimal (U.S. Department of the Navy, 2013d).

In open ocean areas, vessel strikes of vegetation would be limited to floating marine algae. Vessel and in-water device movements may disperse or injure floating algal mats. Because algal distribution is patchy, mats may re-form, and events would be on a small spatial scale, Navy training activities involving vessel movement would not affect the general health of marine algae. Navy mitigation measures would ensure that vessels avoid large algal mats, such as detached kelp paddies or Sargassum, or other sensitive vegetation that other marine life depend on for food or habitat; these measures would safeguard this vegetation type from vessel strikes. This Standard Operating Procedure for vessels is "Watch personnel monitor their assigned sectors for any indication of danger to the ship and the personnel on board, such as a floating or partially submerged object or piece of debris, periscope, surfaced submarine, wisp of smoke, flash of light, or surface disturbance." In addition, as a standard collision avoidance procedure, prior to deploying a towed in-water device from a manned platform, the Navy searches the intended path of the device for any floating debris, objects, or animals (e.g., driftwood, concentrations of floating vegetation, marine mammals) that have the potential to obstruct or damage the device. This standard operating procedure benefits marine mammals, sea turtles, and vegetation through a reduction in the potential for physical disturbance and strike by a towed in-water device.

F.3.4.2 Effects from Military Expended Materials

Military expended materials can potentially affect marine vascular plants on the seafloor by disturbing, crushing, or shading, which may interfere with photosynthesis. In the event that a marine vascular plant is not able to photosynthesize, its ability to produce energy is compromised. However, the intersection of marine vascular plants and military expended materials is limited. Marine vascular plants generally grow in waters that are sheltered from wave action such as estuaries, lagoons, and bays (Phillips & Meñez, 1988). Locations for the majority of Navy training and testing activities where military materials are expended do not provide this type of habitat. The potential for detectable effects on marine vascular plants from expended materials would be based on their size or low density (e.g., small projectiles, small decelerators/parachutes, endcaps, and pistons) of the majority of the materials that could be used in or drift into these areas from offshore. Larger, denser materials, such as non-explosive practice munitions and sonobuoys would be used farther offshore and are likely to sink rapidly where they land. Falling materials could cause bottom sediments to be suspended. Resuspension of the sediment could affect water quality and decrease light exposure, but since it would be short-term (hours), stressors from military expended materials would not likely affect the general health of marine vascular plants.

The following are descriptions of the types of military expended materials that could affect marine algae and marine vascular plants. Marine algae could overlap with military expended materials anywhere in the Study Area; however, the Silver Strand Training Complex is the only location in the Study Area where these materials could overlap with marine vascular plants.

Small-, Medium-, and Large-Caliber Projectiles. Small-, medium-, and large-caliber non-explosive practice munitions, or fragments of high-explosive projectiles, expended during training and testing activities rapidly sink to the seafloor. The majority of these projectiles would be expended in the open ocean areas of the Hawaii Study Area and California Study Area. Because of the small sizes of the projectiles and their casings, damage to marine vegetation is unlikely. Large-caliber projectiles are primarily used in offshore areas at depths greater than 85 ft., while small- and medium-caliber projectiles may be expended in both offshore and coastal areas (at depths mostly less than 85 ft.) within special use airspace in the California Study Area Warning Area 291 (W-291) and at selected areas on San Clemente Island (SCI). Marine algae could occur where these materials are expended, but seagrasses generally do not because these activities do not normally occur in water that is shallow enough for seagrass to grow.

Bombs, Missiles, and Rockets. Bombs, missiles, and rockets, or their fragments (if high-explosive) are expended offshore (at depths mostly greater than 85 ft.) during training and testing activities, and rapidly sink to the seafloor. Marine algae could occur where these materials are expended. However, marine vascular plants generally would not occur where these materials are expended because these activities do not normally occur in water that is shallow enough for marine vascular plants to grow.

Decelerators/Parachutes. Decelerators/parachutes of varying sizes are used during training and testing activities. The types of activities that use decelerators/parachutes, the physical characteristics of these expended materials, where they are used, and the number of activities that would occur under each alternative are discussed in Section F.3.5 (Entanglement Stressors). Kelp, other marine algae, and marine vascular plants could occur where these materials are expended.

Targets. Many training and testing activities use targets. Targets that are hit by munitions could break into fragments. Target fragments vary in size and type, but most fragments are expected to sink. Pieces of targets that are designed to float are recovered when practical. Target fragments would be spread out over large areas. Marine algae could occur where these materials are expended.

Countermeasures. Defensive countermeasures (e.g., chaff, flares, and acoustic devices) are used to protect against incoming weapons (e.g., missiles). Chaff is made of aluminum-coated glass fibers, and flares are pyrotechnic devices. Chaff, chaff canisters, and flare end caps are expended materials. Chaff and flares are dispensed from aircraft or fired from ships. Floating marine algal mats could occur in any of the locations that these materials are expended.

F.3.4.3 Effects from Seafloor Devices

Most seafloor device use would occur in the California Study Area. Seafloor devices use sandy substrates, devoid of marine vegetation, to the greatest extent practicable. Marine plant species found within the relatively shallow waters of the Study Area, including the Hawaii Range Complex and off SCI, are adapted to natural disturbance and recover quickly from storms, as well as from wave and surge action. Bayside marine plant species, such as eelgrass, are found in areas where wave action is minimal. Installation of seafloor devices may affect vegetation in benthic habitats, but the effects would be temporary and would be followed by rapid (i.e., within a few weeks) recovery, particularly in oceanside boat lanes in nearshore waters off San Diego and in designated training areas adjoining SCI. Eelgrass beds show signs of recovery after a cessation of physical disturbance; the rate of recovery is a function of the severity of the disturbance (Neckles et al., 2005). The main factors that contribute to eelgrass recovery include improving water quality and cessation of major disturbance activities (e.g., dredging) (Chavez, 2009). The Navy has used credits from the Navy Region Southwest San Diego Bay Eelgrass Mitigation Bank (Bank) to offset unavoidable eelgrass and other habitat effects from infrastructure projects and testing and training activities in San Diego Bay (U.S. Department of the Navy, 2023).

New range modernization and sustainment activities include installation of undersea cables integrated with hydrophones and underwater telephones to sustain the capabilities of the Southern California Anti-Submarine Warfare Range. Deployment of fiber-optic cables along the seafloor would occur in three locations: south and west of SCI in the California Study Area, to the northeast of Oahu in the Hawaii Study Area, and to the west of Kauai in the Hawaii Study Area. In all locations the installations would occur completely within the water; no land interface would be involved. Cable-laying activities in the California Study Area could disturb marine vegetation when the cable crosses rocky substrate at depths between 65 and 196 ft. (20 and 60 m) for the Shallow Water Training Range Extension. However, it is anticipated that rocky substrate would be avoided to the greatest extent possible throughout the cable corridor to minimize these effects.

Installation and maintenance of underwater platforms, mine warfare training areas, and installation of other training areas involve seafloor disturbance where those activities would take place. Each installation would occur on soft, typically sandy bottom, avoiding rocky substrates.

F.3.4.4 Effects from Pile Driving

Pile driving would not affect vegetation on the sea surface, such as marine algal mats; therefore, floating vegetation will not be discussed further in this section. Pile driving would occur only in Port Hueneme Harbor near existing piers where the area is disturbed.

Pile driving could affect marine vascular plants and seafloor macroalgae by physically removing vegetation (e.g., uprooting); crushing vegetation; temporarily increasing the turbidity (sediment suspended in the water) of waters nearby; or shading, which may interfere with photosynthesis. If vegetation is not able to photosynthesize, its ability to produce energy is compromised. However, the intersection of marine macroalgae and marine vascular plants with pile driving is limited, and any suspended sediments would settle in a few days.

In bay areas, recovery of marine vascular plants such as eelgrass from direct disturbance by pile driving would occur over longer timeframes. Eelgrass beds show signs of recovery after a cessation of physical disturbance; the rate of recovery is a function of the severity of the disturbance (Neckles et al., 2005). The main factors that contribute to eelgrass recovery include improved water quality and cessation of major disturbance activities (e.g., dredging) (Chavez, 2009). Pile driving, in contrast to dredging, has a minor effect that is limited to the area of the actual pile and footprint of the mooring.

F.3.5 Entanglement Stressors

Entanglement stressors are not applicable vegetation and are therefore not analyzed further in this section.

F.3.6 Ingestion Stressors

Ingestion stressors are not applicable to vegetation and are therefore not analyzed further in this section.

F.3.7 Secondary Stressors

This section analyzes potential effects on marine vegetation exposed to stressors indirectly through effects on habitat and prey availability.

F.3.7.1 Effects on Habitat

Section 3.2 (Sediments and Water Quality) and Section 3.5 (Habitats) consider the effects on marine sediments and water quality and abiotic habitats from explosives and explosion byproducts, metals, chemicals other than explosives, and other materials (marine markers, flares, chaff, targets, and miscellaneous components of other materials). One example from the sediment and water quality analysis of a local effect on water quality could be an increase in cyanobacteria associated with munitions deposits in marine sediments. Cyanobacteria may proliferate when iron is introduced to the marine environment, and this proliferation can affect adjacent habitats by releasing toxins and can create hypoxic conditions. Introducing iron into the marine environment from munitions or infrastructure is not known to cause toxic red tide events; rather, these harmful events are more associated with natural causes (e.g., upwelling) and the effects of other human activities (e.g., agricultural runoff and other coastal pollution) (Hayes et al., 2007). High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Many combustion products are common seawater constituents. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives

Byproducts). Explosives byproducts from high-order detonations present no indirect stressors to marine vegetation through sediment or water.

The analysis included in Section 3.2 (Sediments and Water Quality) determined that neither state nor federal standards or guidelines for sediments or water quality would be violated by the No Action Alternative, Alternative 1, or Alternative 2. Because standards for sediment and water quality would not be violated, population-level effects on marine vegetation are not likely to be detectable and are therefore inconsequential. Therefore, because these standards and guidelines are structured to protect human health and the environment, and the proposed activities do not violate them, no indirect effects are anticipated on vegetation from the training and testing activities proposed by the No Action Alternative, Alternative 1, or Alternative 2.

Other materials that are re-mobilized after their initial contact with the seafloor (e.g., by waves or currents) may continue to strike or abrade marine vegetation. Secondary physical strike and disturbances are relatively unlikely because most expended materials are denser than the surrounding sediments (e.g., metal) and are likely to remain in place as the surrounding sediment moves. Potential secondary physical strike and disturbance effects may cease when (1) the military expended material is too massive to be mobilized by typical oceanographic processes, (2) the military expended material becomes encrusted by natural processes and incorporated into the seafloor, or (3) the military expended material becomes permanently buried. Although individual organisms could be affected by secondary physical strikes, the viability of populations or species would not be affected.

F.3.7.2 Effects on Prey Availability

Prey availability as a stressor is not applicable to vegetation and will not be analyzed further in this section.

F.4 Invertebrates

F.4.1 Acoustic Stressors

F.4.1.1 Background

A summary of available information related to each type of effect is presented in the following sections. Some researchers discuss effects in terms of the acoustic near field and far field. The near field is an area near a sound source where considerable interference between sound waves emerging from different parts of the source is present. Amplitude may vary widely at different points within this acoustically complex zone, and sound pressure and particle velocity are generally out of phase. The far field is the distance beyond which sound pressure and particle velocity are in phase, all sound waves appear to originate from a single point, and pressure levels decrease predictably with distance. The boundary between the near and far field is frequency-dependent, with the near field extending farther at lower frequencies. It has been estimated that the near field for a sound of 500 Hertz (Hz) (intensity not specified) would extend about 3 m from the source (Myrberg, 2001).

F.4.1.1.1 Injury

Injury refers to the direct effects on the tissues or organs of an animal due to exposure to pressure waves or particle motion. Available information on injury to invertebrates resulting from acoustic sources pertains mostly to damage to the statocyst, an organ sensitive to water particle motion and responsible for balance and orientation in some invertebrates. A few studies have also investigated effects to appendages and other organs, and one study investigated zooplankton mortality in response to air gun firing.

Researchers have investigated the effects of noise on American lobsters exposed to air gun firings in an aquarium and in the field (Payne et al., 2007). Lobsters in the aquarium were placed about 3.5 m from the air guns and exposed to sound levels of about 200 dB (peak-to-peak). Caged lobsters in the field were located 2 m from the air guns and exposed to higher-intensity sound levels (about 230 dB peak-to-peak). No physical damage to appendages and no effects on balance or orientation (indicating no damage to statocysts) were observed in any lobsters. No visible evidence of damage to hepatopancreata (digestive glands) or ovaries were found. Caged snow crabs (*Chionoecetes opilio*) were exposed to repeated air gun firings in the field (Christian et al., 2003). Crabs exposed to a single air gun were placed at depths of 2–15 m, while crabs exposed to air gun arrays were placed at depths of 4–m. Air guns were fired during multiple sessions, with each session consisting of a firing every 10 seconds for 33 minutes. Peak received levels were up to 207 dB re 1 µPa and 187 decibels referenced to 1 squared micropascal (dB re 1 µPa^2) (single gun), and 237 dB re 1 µPa and 175 dB re 1 µPa^2 (array). Post-experimental examination showed no physical damage to statocysts, hepatopancreata, heart muscle or surrounding tissue, carapace, or appendages. As a comparison, air guns operated at full capacity during Navy activities would produce an SPL of approximately 206 dB re 1 µPa root mean squared (rms) and a sound exposure level (SEL) of 185–196 decibels referenced to 1 micropascal squared per second (dB re 1 µPa^2-s) at a distance 1 m from the air gun. Air guns are also operated at less than full capacity, resulting in reduced sound levels.

In three instances, seismic air gun use has been hypothesized as the cause of giant squid strandings. This was based on the proximity in time and space of the squid and operating seismic vessels and, in two of the events, to physical injuries considered consistent with exposure to impulsive acoustic waves (Guerra & Gonzales, 2006; Guerra et al., 2004; Leite et al., 2016). However, because the animals were not observed at the time of potential effect, the cause(s) of the injuries and strandings cannot be determined conclusively.

Zooplankton abundance and mortality was investigated in the context of exposure to air gun firings in an open ocean environment (McCauley et al., 2017). Net tows and sonar surveys were conducted after transects involving air gun firings were completed. The results indicated decreased zooplankton abundance and increased mortality as a result of exposure. The most abundant organisms (copepods and cladocerans [water fleas]) showed a 50 percent decrease in abundance at distances of about 500 to 700 m from the source. Received noise level at this distance was about 156 dB re 1 µPa^2-s SEL and 183 dB re 1 µPa peak-to-peak. There was no effect on the abundance of these specific taxa at distances of about 1 kilometer (km) from the source (153 dB re 1 µPa^2-s SEL and 178 dB re 1 µPa peak-to-peak). However, an overall decrease in zooplankton abundance was reported at distances to about 1.2 km from the source. The authors speculated that the effects could have been caused by damage to external sensory hairs on the organisms.

Physiological studies of wild captured cephalopods found progressive damage to statocysts in squid and octopus species after exposure to two hours of low-frequency (50–400 Hz) sweeps (100 percent duty cycle) at SPL of 157 to 175 dB re 1 µPa (André et al., 2011; Sole et al., 2013). It is noted that the animals were in the near field (distance was not specified in the report, but animals were likely within a few to several feet of the sound source based on the experiment description), where there is significant particle motion. In a similar experiment designed to control for possible confounding effects of experimental tank walls, common cuttlefish (*Sepia officinalis*) were exposed to two hours of low-frequency sweeps (100 to 400 Hz; 100 percent duty cycle with a 1-second sweep period) in an offshore environment (Sole et al., 2017). Sounds were produced by a transducer located near the surface, and caged experimental animals were placed at depths between 7 and 17 m. Received sound levels ranged from 139 to 142 dB re 1 μPa^2. Maximum particle motion of 0.7 meter per squared second was recorded at the cage nearest the transducer (7.1 m between source and cage). Progressive damage to sensory hair cells of the statocysts were found immediately after and 48 hours after sound exposure, with the severity of effects being proportional to distance from the transducer. The authors suggest that whole-body vibrations resulting from particle motion were transmitted to the statocysts, causing damage to the structures. Statocyst damage was also found in captive individuals of two jellyfish species (Mediterranean jellyfish [*Cotylorhiza tuberculata*] and barrel jellyfish [*Rhizostoma pulmo*]) under the same exposure parameters (50–400 Hz sweeps; two-hour exposure time; 100 percent duty cycle with a one-second sweep period; approximately 157 to 175 dB re 1 µPa received SPL) (Sole et al., 2016). In the context of overall invertebrate population numbers, most individuals exposed to acoustic stressors would be in the far field where particle motion would not occur and, therefore, the types of damage described above would not be expected. In addition, exposure duration would be substantially less than two hours.

This limited information suggests that the potential for statocyst damage may differ according to the type of sound (impulsive or continuous) or among invertebrate taxa (e.g., crustaceans and cephalopods). Therefore, a definitive conclusion regarding potential effects on invertebrates in general is unsupported. Although invertebrate occurrence varies based on location, depth, season, and time of day (for example, the rising of the deep scattering layer, which consists of numerous invertebrate taxa), individuals could be present in the vicinity of impulsive or non-impulsive sounds produced by Navy activities. Estimation of invertebrate abundance at any particular location would generally not be feasible, but there is a general pattern of higher abundances in relatively productive estuarine and nearshore waters compared to abundances in offshore portions of the Study Area. The number of individuals affected would be influenced by sound sensing capabilities. As discussed in Section 3.4.3.1 (Acoustic Stressors), invertebrate acoustic sensing is probably limited to the particle motion component of sound. Water particle motion is most detectable near a sound source and at lower frequencies, which likely limits the range at which invertebrates can detect sound.

F.4.1.1.2 Physiological Stress

A stress response consists of one or more physiological changes (e.g., production of certain hormones) that help an organism cope with a stressor. However, if the magnitude or duration of the stress response is too great or too prolonged, there can be negative consequences to the organism. Physiological stress is typically evaluated by measuring the levels of relevant biochemicals in the subject organisms.

The results of two investigations of physiological stress in adult invertebrates caused by impulsive noise varied by species. Some biochemical stress markers and changes in osmoregulation were observed in American lobsters exposed to air gun firings at distances of approximately 2–4 m from the source (Payne et al., 2007). Increased deposits of carbohydrates, suggesting a possible stress response, were noted in digestive gland cells four months after exposure. Conversely, repeated air gun exposures caused no changes in biochemical stress markers in snow crabs located from 2 to 170 m from the source (Christian et al., 2003).

Several investigations of physiological reactions of captive adult invertebrates exposed to boat noise playback and other continuous noise have been conducted. Continuous exposure to boat noise playback resulted in changes to some biochemical levels indicating stress in common prawns (*Palaemon serratus*) (30-minute exposure to sound levels of 100 to 140 dB re 1 µPa rms) and European spiny lobsters

(30-minute exposure to sound levels up to 125 dB re 1 µPa rms) (Celi et al., 2015; Filiciotto et al., 2016; Filiciotto et al., 2014). Increased oxygen consumption, potentially indicating stress, was found in shore crabs exposed to ship-noise playback of 148 to 155 dB re 1 µPa for 15 minutes (Wale et al., 2013b). Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 25 kilohertz (kHz), peak amplitude of 148 dB rms at 12 kHz) showed changes in some biochemical levels indicating stress (Celi et al., 2013). Captive sand shrimp (*Crangon crangon*) exposed to low-frequency noise (30 to 40 dB above ambient) continuously for three months demonstrated decreases in growth rate and reproductive rate (Lagardère, 1982). Mediterranean mussels (*Mytilus galloprovincialis*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 µPa), although exhibiting no behavioral changes at any tested frequency, showed statistically significant increases in some biochemical stress indicators (e.g., glucose and heat shock protein) in the low-frequency exposure category (0.1 to 5 kHz) (Vazzana et al., 2016). Changes in glucose levels were found in blue crabs (*Callinectes sapidus*) exposed to low-frequency sound (broadband noise with a significant component of 60 Hz at approximately 170 dB re 1 µPa SPL) and mid-frequency pulsed tones and chirps (1.7 to 4 kHz at approximately 180 dB re 1 µPa SPL) (Dossot et al., 2017).

In addition to experiments on adult invertebrates, some studies have investigated the effects of impulsive and non-impulsive noise (air guns, boat noise, turbine noise) on invertebrate eggs and larvae. Data on similar effects resulting from sonar are currently unavailable. Developmental delays and body malformations were reported in New Zealand scallop (*Pecten novaezelandiae*) larvae exposed to seismic air gun playbacks at frequencies of 20 Hz to 22 kHz with SPL of 160–164 dB re 1 µPa (Aguilar de Soto et al., 2013). Although uncertain, the authors suggested physiological stress as the cause of the effects. Larvae in the relatively small (2 m diameter) experimental tank were considered close enough to the acoustic source to experience particle motion, which would be unlikely at the same pressure levels in the far field. Playbacks occurred once every three seconds and the larvae were periodically examined over the course of 90 hours. Snow crab (*Chionoecetes opilio*) eggs located in 2 m water depth and exposed to repeated firings of a seismic air gun (peak received SPL was 201 dB re 1 µPa) had slightly increased mortality and apparent delayed development (Christian et al., 2003). However, Dungeness crab (*Metacarcinus magister*) zoeae were not affected by repeated exposures to an air gun array (maximum distance of about 62 ft. slant distance) (Pearson et al., 1994), and exposure of southern rock lobster (*Jasus edwardsii*) eggs to air gun SELs of up to 182 dB re 1 μPa^2-s did not result in embryonic developmental effects (Day et al., 2016). An investigation of the effects of boat noise playback on the sea hare (*Stylocheilus striatus*) found reduced embryo development and increased larvae mortality, but no effect on the rate of embryo development (Nedelec et al., 2014). Specimens were exposed to boat-noise playback for 45 seconds every five minutes over a 12-hour period. Continuous playback of simulated underwater tidal and wind turbine sounds resulted in delayed metamorphosis in estuarine crab larvae (*Austrohelice crassa* and *Hemigrapsus crenulatus*) that were observed for up to about 200 hours (Pine et al., 2016).

Overall, the results of these studies indicate the potential for physiological effects in some, but not all, adult invertebrates exposed to air guns near the source (about 2–4 m) and to boat and other continuous noise for durations of 15–30 minutes or longer. Larvae and egg development effects were reported for impulsive (distance from source of about 2 m) and non-impulsive noise exposures of extended duration (intermittently or continuously for several to many hours) and for air gun playback and field exposure, although air gun noise had no effect in one study. In general, exposure to continuous noise such as vessel operation during Navy training or testing events would occur over a shorter duration and sound sources would be more distant than those associated with most of the studies. Adverse effects resulting from short exposure times have not been shown experimentally. A range to effects was not systematically investigated for air gun use. Experiments using playback of air gun and boat noise were conducted in relatively small tanks where particle motion, which decreases rapidly with distance, could have been significant. Marine invertebrate egg and larval abundances are high relative to the number of adults, and eggs and larvae are typically subject to high natural mortality rates. These factors decrease the likelihood of population-level effects resulting from effects on eggs and larvae from physiological stress associated with Navy training and testing events.

F.4.1.1.3 Masking

Masking occurs when one sound interferes with the detection or recognition of another sound. Masking can limit the distance over which an organism can communicate or detect biologically relevant sounds. Masking can also potentially lead to behavioral changes.

Little is known about how marine invertebrates use sound in their environment. Some studies show that crab, lobster, oyster, and coral larvae and post-larvae may use nearby reef sounds when in their settlement phase. Orientation and movement toward reef sounds was found in larvae located at 60–80 m from a sound source in open water, and in experimental tanks (distance from the sound source was about 150 cm in one laboratory study) (Radford et al., 2007; Stanley et al., 2010; Vermeij et al., 2010). The component of reef sound used is generally unknown, but an investigation found that low-frequency sounds (200–1,000 Hz) produced by fish at dawn and dusk on a coral reef were the most likely sounds to be detectable a short distance from the reef (Kaplan & Mooney, 2016). Similarly, lobed star coral larvae were found to have increased settlement on reef areas with elevated sound levels, particularly in the frequency range of 25–1,000 Hz (Lillis et al., 2016). Mountainous star coral (*Orbicella faveolata*) larvae in their settlement phase were found to orient toward playbacks of reef sounds in an experimental setup, where received sound levels were about 145–149 dB re 1 µPa and particle velocity was about 9×10^{-8} meters per second (Vermeij et al., 2010). Marine invertebrates may also use sound to communicate and avoid predators (Popper et al., 2001). Crabs (*Panopeus* species) exposed to playback of predatory fish vocalizations reduced foraging activity, presumably to avoid predation risk (Hughes et al., 2014). The authors suggest that, due to lack of sensitivity to sound pressure, crabs are most likely to detect fish sounds when the fish are nearby. Anthropogenic sounds could mask important acoustic cues such as detection of settlement cues or predators, and potentially affect larval settlement patterns or survivability in highly modified acoustic environments (Simpson et al., 2011). Low-frequency sounds could interfere with perception of low-frequency rasps or rumbles among crustaceans, particularly when conspecific sounds are produced at the far end of the hearing radius. Navy activities occurring relatively far from shore would produce transient sounds potentially resulting in only intermittent, short-term masking, and would be unlikely to affect the same individuals within a short time. Training and testing activities would generally not occur at known reef sites within the probable reef detection range of larvae. Effects could be more likely in locations where anthropogenic noise occurs frequently within the perceptive range of invertebrates (e.g., pierside locations in estuaries). There are likely many other non-Navy noise sources present in such areas, and potential effects on invertebrates would be associated with all anthropogenic sources.

F.4.1.1.4 Behavioral Reactions

Behavioral reactions refer to alterations of natural behaviors due to exposure to sound. Most investigations involving invertebrate behavioral reactions have been conducted in relation to air gun use, pile driving, and vessel noise. Studies of air gun effects on marine invertebrates (crustaceans and cephalopods) have typically been conducted with equipment used for seismic exploration, and the limited results suggest responses may vary among taxa. Snow crabs placed 48 m below a seismic air gun array did not react behaviorally to repeated firings (peak received SPL was 201 dB re 1 µPa) (Christian et al., 2003). Studies of commercial catch of rock lobsters (*Panulirus cygnus*) and multiple shrimp species in the vicinity of seismic prospecting showed no long-term adverse effects to catch yields, implying no detectable long-term effects on abundance from intermittent anthropogenic sound exposure over long periods (Andriguetto-Filho et al., 2005; Parry & Gason, 2006). Conversely, squid have exhibited various behavioral reactions when exposed to impulsive noise such as air gun firing (McCauley et al., 2000). Some squid showed strong startle responses, including inking, when exposed to the first shot of broadband sound from a nearby seismic air gun (received SEL of 174 dB re 1 µPa rms) Strong startle response was not seen when sounds were gradually increased, but the squid exhibited alarm responses at levels above 156 dB re 1 µPa rms (McCauley et al., 2000). Southern reef squids (*Sepioteuthis australis*) exposed to air gun noise displayed alarm responses at levels above 147 dB re 1 µPa^2-s (Fewtrell & McCauley, 2012).

Pile driving produces sound pressure that moves through the water column and into the substrate, which may therefore affect both pelagic and benthic invertebrates. Impact pile driving produces a repetitive impulsive sound, while vibratory pile extraction produces a nearly continuous sound at a lower source level. Although few investigations have been conducted regarding effects on invertebrates resulting from impact pile driving and extraction, the effects are likely similar to those resulting from other impulsive and vibrational (e.g., drilling) sources. When an underwater sound encounters the substrate, particle motion can be generated, resulting in vibration. Invertebrates may detect and respond to such vibrations. Playback of impact pile driving sound (137–152 dB re 1 µPa peak to peak) in the water column near chorusing snapping shrimp resulted in an increase in the snap number and amplitude (Spiga, 2016). When exposed to playback of broadband impulsive pile driving sound of 150 dB SEL, Japanese carpet shell clams (*Ruditapes philippinarum*) exhibited reduced activity and valve closing, while Norway lobsters (*Nephrops norvegicus*) repressed burying, bioirrigation, and locomotion activity (Solan et al., 2016). Brittlestars (*Amphiura filiformis*) included in the experiment exhibited no overall statistically detectable behavioral changes, although the authors note that a number of individuals exhibited changes in the amount of sediment reworking activity. Pacific oysters (*Magallana gigas*) exposed to three-minute pure tones responded behaviorally (shell closure) to low-frequency sounds, primarily in the range of 10–200 Hz (Charifi et al., 2017). The oysters were most sensitive to sounds of 10–80 Hz at 122 dB rms re 1 µPa, with particle acceleration of 0.02 meter per squared second. Invertebrates exposed to vibrations of 5–410 Hz (which is a proxy for the effects of vibratory pile removal) at various particle acceleration amplitudes in the substrate of a holding tank for eight-second intervals exhibited behavioral reactions ranging from valve closure (common mussel [*Mytilus edulis*]) to antennae sweeping, changes in locomotion, and exiting the shell (common hermit crab [*Pagurus bernhardus*]) (Roberts et al., 2015; Roberts et al., 2016a). Sensitivity was greatest at 10 Hz and at particle acceleration of 0.1 m per squared second. The authors analyzed data on substrate acceleration produced by pile driving in a river and found levels that would be detectable by the hermit crabs at 17 and 34 m from the source. Measurements were not available for other distances or in marine environments. Similarly, underwater construction-related detonations of about 14-pound (lb.) charge weight (presumably in fresh water) resulted in substrate vibrations 297 m from the source that would likely be detected by crabs. Follow-up experiments showed that particle acceleration detection sensitivity in mussels and hermit crabs ranged from 0.06 to 0.55 meters per squared second (Roberts et al., 2016b). Subsequent semi-field experiments consisted of operating a small pile driver for two-hour periods in an enclosed dock (90 m long by 18 m wide, water depth of 2–3 m, and sediment depth of 3 to 4 m). Vibration in the sediment propagated farther (up to 30 m) in shallower water than in deeper water (up to 15 m). The signal in the sediment was mostly below 100 Hz and primarily from 25 to 35 Hz. Experimental animals in the enclosed area exhibited behavioral (e.g., width of shell opening) and physiological (e.g., oxygen demand) responses as a result of exposure, although information such as distance from the pile driver and particle acceleration at specific locations was not provided.

Common prawns and European spiny lobsters exposed to 30 minutes of boat noise playback in frequencies of 200 Hz to 3 kHz (sound levels of approximately 100 to 140 dB SPL [prawns] and 75 to 125 dB SPL [lobsters]) showed behavioral responses including changes in movement velocity, and distance moved, as well as time spent inside a shelter (Filiciotto et al., 2016; Filiciotto et al., 2014). Common cuttlefish exposed to playback of underwater ferry engine noise for 3.5 minutes (maximum sound level of about 140 dB re 1 µPa SPL) changed color more frequently, swam more, and raised their tentacles more often than control specimens or individuals exposed to playback of wave sounds (Kunc et al., 2014). Shore crabs (*Carcinus maenas*) exposed to ship noise playback did not exhibit changes in the ability or time required to find food, but feeding was often suspended during the playback (Wale et al., 2013a). Japanese carpet shell clams and Norway lobsters exposed to playback of ship noise for seven days at received levels of 135–140 dB re 1 µPa exhibited reactions such as reduced activity, movement, and valve closing (Solan et al., 2016). Brittlestars (*A. filiformis*) included in the study showed no overall statistically detectable behavioral changes, although individual animals were affected. Antarctic krill (*Euphausia superba*) did not respond to a research vessel approaching at 2.7 knots (source level below 150 dB re 1 µPa) (Brierley et al., 2003). Decreased activity levels were found in blue crabs exposed to low-frequency broadband sound with a significant component of 60 Hz (approximately 170 dB re 1 µPa SPL) and mid-frequency pulsed tones and chirps (1.7 –4 kHz at approximately 180 dB re 1 µPa SPL) (Dossot et al., 2017). Exposure to low-frequency sounds resulted in more pronounced effects than exposure to mid-frequency sounds. American lobsters appeared to be less affected than crabs.

A limited number of studies have investigated behavioral reactions to non-impulsive noise other than that produced by vessels. Red swamp crayfish (*Procambarus clarkii*) exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1–25 kHz, peak amplitude of 148 dB rms at 12 kHz) exhibited changes in social behaviors (Celi et al., 2013). Caribbean hermit crabs (*Coenobita clypeatus*) delayed reaction to an approaching visual threat when exposed to continuous noise (Chan et al., 2010a; Chan et al., 2010b). The delay potentially put them at increased risk of predation, although the studies did not address possible simultaneous distraction of predators. Razor clams (*Sinonovacula constricta*) exposed to white noise and sine waves of 500 and 1,000 Hz responded by digging at a sound level of about 100 dB re 1 µPa (presumably as a defense reaction) but did not respond to sound levels of 80 dB re 1 µPa (Peng et al., 2016). Mediterranean mussels exposed to 30-minute continuous acoustic sweeps (frequency range of 0.1 to 60 kHz, maximum SPL of 150 dB rms re 1 µPa) showed no statistically significant behavioral changes compared to control organisms (Vazzana et al., 2016).

The results of these studies indicate that at least some invertebrate taxa would respond behaviorally to various levels of sound and substrate vibration produced within their detection capability. Comprehensive investigations of the range to effects of different sound and vibration sources and levels are not available. However, sound source levels for Navy pile diving and air gun use are within the range of received levels that have caused behavioral effects in some species (Solan et al., 2016). The low-frequency component of vessel noise would likely be detected by some invertebrates, although the number of individuals affected would be limited to those near enough to a source to experience particle motion.

F.4.1.2 Effects from Sonar and Other Transducers

Many non-impulsive sounds associated with training and testing activities are produced by sonar. Other transducers include items such as acoustic projectors and countermeasure devices. Most marine invertebrates do not have the capability to sense sound pressure; however, some are sensitive to nearby low-frequency sounds, such as could be approximated by some low-frequency sonars. As described in Section 3.4.3.1 (Acoustic Stressors), invertebrate species detect sound through particle motion, which diminishes rapidly with distance from the sound source. Therefore, the distance at which they may detect a sound is probably limited. Most activities using sonar or other transducers would be conducted in deep-water, offshore portions of the Study Area and are not likely to affect most benthic invertebrate species (including ESA-listed abalone species), although invertebrates in the water column could be affected. However, portions of the range complexes overlap nearshore waters of the continental shelf, and it is possible that sonar and other transducers could be used and affect benthic invertebrates in these areas. Sonar is also used in shallow water during pierside testing and maintenance testing.

Invertebrate species generally have their greatest sensitivity to sound below 1 to 3 kHz (Kunc et al., 2016) and would therefore not be capable of detecting mid- or high-frequency sounds, including the majority of sonars, or distant sounds in the Study Area. Studies of the effects of continuous noise such as boat noise, acoustic sweeps, and tidal/wind turbine sound (information specific to sonar use was not available) on invertebrates have found statocyst damage, elevated levels of biochemicals indicative of stress, changes in larval development, masking, and behavioral reactions under experimental conditions (see Section 3.4.2.1, General Background). Noise exposure in the studies generally lasted from a few minutes to 30 minutes. The direct applicability of these results is uncertain because the duration of sound exposure in many of the studies is greater than that expected to occur during Navy activities, and factors such as environmental conditions (captive versus wild conditions) may affect individual responses (Celi et al., 2013). Individuals of species potentially susceptible to statocyst damage (e.g., some cephalopods) could be physically affected by nearby noise. Available research has shown statocyst damage to occur after relatively long-duration exposures (two hours), which would be unlikely to occur to individual invertebrates due to transiting sources and potential invertebrate movement. An exception is pierside sonar testing and maintenance testing, where invertebrates (particularly sessile or slow-moving taxa such as bivalve molluscs, hydroids, and marine worms) could be exposed to sound for longer time periods compared to at-sea activities. Some studies also indicate the potential for effects on invertebrate larval development resulting from exposure to non-impulsive noise (continuous or intermittent exposures over time periods of 12 to 200 hours) although, similar to stress effects, sonar has not been studied specifically. Masking could affect behaviors such as larvae settlement, communication, predator avoidance, and foraging in mollusc, crustacean, and coral species.

F.4.1.3 Effects from Air Guns

Air guns produce shock waves that are somewhat similar to those produced by explosives (see Section 3.4.3.2, Explosives Stressors) but of lower intensity and slower rise times. An impulsive sound is generated when pressurized air is released into the surrounding water. Some studies of air gun effects on marine invertebrates have involved the use of an array of multiple seismic air guns, although arrays are not used during Navy training and testing activities. The volume capacity of air guns used for Navy testing (60 cubic inches at full capacity) is generally within the volume range of single air guns used in seismic exploration (typically 20–800 cubic inches). However, seismic air guns are used in arrays with a total volume of several thousands of cubic inches, which is far more than would be associated with any Navy activities. Generated impulses would have short durations, typically a few hundred milliseconds. The root-mean-squared SPL and SEL at a distance of 1 m from the air gun would be approximately 200 to 210 dB re 1 µPa and 185 to 195 dB re 1 μPa^2-s, respectively.

The results of studies of the effects of seismic air guns on marine invertebrates, described in detail in Section 3.4.3.1 (Acoustic Stressors), suggest possible differences between taxonomic groups and life stages. Physical injury has been reported in relatively few crustaceans (crabs, shrimp, and lobsters) exposed to seismic air guns at received levels comparable to the source level of Navy air guns operated at full capacity, but one study reported injury and mortality for zooplankton at exposures below Navy source levels. Evidence of physiological stress was not found in crabs exposed to sound levels up to 187 dB re 1 μPa^2. However, stress response was reported for lobsters located about 3.5 m from the source, where particle motion was likely detectable. While behavioral reaction to air guns has not been documented for crustaceans, squid have exhibited startle and alarm responses at various sound levels. Squid have shown startle response at received levels of 156–174 dB re 1 µPa rms (distance from sound source is unclear but presumed to be 30 m based on experimental description), although the reactions were less intense when ramp-up procedures (beginning with lower-intensity sound and progressing to higher levels) were used. In one study, onset of alarm response occurred at 147 dB re 1 μPa^2-s; distance from the source was not provided. Developmental effects to crab eggs and scallop larvae were found at received levels of 210 and 164 dB 1 µPa SPL (about 7 ft. from the source). Conversely, crab zoeae located 62 ft. from an air gun source showed no developmental effects. Air gun use could also result in substrate vibration, which could cause behavioral effects in nearby benthic invertebrates.

F.4.1.4 Effects from Pile Driving

Effects on invertebrates resulting from pile driving and removal are considered in the context of impulsive sound and substrate vibration. Impact pile driving produces a pressure wave that is transmitted to the water column and the sediment (Reinhall & Dahl, 2011). The pressure wave may cause vibration within the sediment. Most acoustic energy would be concentrated below 1,000 Hz, which is within the general sound sensing range of invertebrates. Available information indicates that invertebrates may respond to particle motion and substrate vibration produced by pile driving or removal. As discussed in Section 3.4.3.1 (Acoustic Stressors), recent investigations have found effects to crustacean and mollusc species resulting from pile driving noise playback and substrate vibration (Roberts et al., 2015; Roberts et al., 2016a; Solan et al., 2016; Spiga, 2016). Responses include changes in chorusing (snapping shrimp), shell closing (clams and mussels), and changes in activity level (clams, lobsters, and hermit crabs). However, no statistically detectable changes were observed in brittlestars, suggesting that effects may vary among taxa or species. While one study was conducted in a sheltered coastal area (Spiga, 2016), the others used small experimental tanks with maximum dimension of about 20 inches (in.). Therefore, many of the effects were observed very close to the sound sources. Navy scientists are in the early stages of observing the response of marine life to pile driving in their unconfined environment using an adaptive resolution imaging sonar that allows observations in low visibility estuarine waters. Samples acquired to date include the response (or lack thereof) of various fish and crabs to Navy pile driving in the Mid-Atlantic region (Chappell, 2018).

F.4.1.5 Effects from Vessel Noise

Physiological effects included biochemical changes indicative of stress in crustacean species, decreased growth and reproduction in shrimp, and changes in sea hare embryo development. It is also possible that vessel noise may contribute to masking of relevant environmental sounds, such as predator detection or reef sounds. Low-frequency reef sounds are used as a settlement cue by the larvae of some invertebrate species. Behavioral effects resulting from boat noise playback have been observed in various crustacean, cephalopod, and bivalve species and include shell closing and changes in feeding, coloration, swimming, and other movements. Exposure to other types of non-impulsive noise (and therefore potentially relevant to vessel noise effects), including continuous sweeps and underwater turbine noise playback, has resulted in statocyst damage (squid and octopus), physiological stress, effects to larval development, and behavioral reactions. Noise exposure in several of the studies using boat and other continuous noise sources occurred over a duration of 3.5–30 minutes to captive individuals unable to escape the stimulus. In other studies, noise playback ranged from hours to days (and up to three months in one investigation) of continuous or intermittent exposure. Given the duration of exposure, direct applicability of the results to Navy training and testing activities is uncertain for mobile species. However, it is possible that invertebrates in the Study Area that are exposed to vessel noise could exhibit similar reactions.

While commercial vessel traffic and associated noise is relatively steady over time, Navy traffic is episodic in the ocean. Activities involving vessel movements occur intermittently and are variable in duration, ranging from a few hours to a few weeks. Vessels engaged in training and testing may consist of a single vessel involved in unit-level activity for a few hours or multiple vessels involved in a major training exercise that could last a few days within a given area. In the West Coast Exclusive Economic Zone, Navy ships are estimated to contribute roughly 10 percent of the total large vessel broadband energy noise (Mintz, 2012).

F.4.1.6 Effects from Weapons Noise

Underwater sound produced by weapons firing, launch, and impact of non-explosive practice munitions would be greatest near the surface and would attenuate with depth. However, the potential for in-air weapons noise to affect invertebrates would be small. Much of the energy produced by muzzle blasts and flying projectiles is reflected off the water surface. As discussed in Section 3.0.3.3.1.6 (Weapon Noise), sound generally enters the water only in a cone beneath the blast or projectile trajectory (within 13 to 14 degrees of vertical for muzzle blast noise, and 65 degrees behind the projectile in the direction of fire for projectile shock waves). An SEL of 180 to 185 dB re 1 μPa^2-s was measured at water depth of 5 ft. directly below the muzzle blast of the largest gun analyzed, at the firing position closest to the water. Different weapons and angles of fire would produce less sound in the water. Bow waves from supersonic projectiles produce a brief “crack” noise at the surface, but transmission of sound into the water is minimal. Launch noise fades rapidly as the missile or target moves downrange and the booster burns out. Hull vibration from large-caliber gunfire produces only a small level of underwater noise. For example, analysis of 5-in. gun firing found that energy transmitted into the water by hull vibration is only 6 percent of that produced by the muzzle blast. Compared to weapons firing, launches, and hull vibration, impulsive sound resulting from non-explosive practice munition strikes on the water surface could affect a somewhat larger area, though far less than an explosive blast. Underwater sound would generally be associated only with relatively large munitions affecting at high speed.

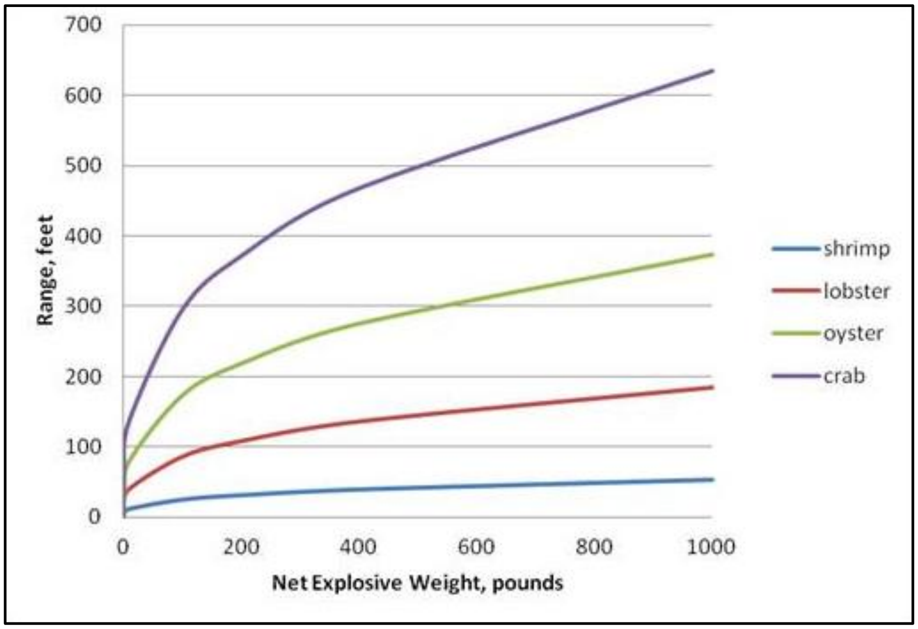
Based on the discussion above, invertebrates would likely only be affected by noise produced by muzzle blasts and impact of large non-explosive practice munitions. Effects would likely be limited to pelagic invertebrates, such as squid, jellyfish, and zooplankton, located near the surface. Injury and physiological stress has not been found in limited studies of invertebrates exposed to impulsive sound levels comparable to those produced beneath the muzzle blast of a 5-in. gun. Behavioral reactions have not been found in crustaceans, but have been observed for squid. While squid could display short-term startle response, behavioral reactions in response to sound is not known for jellyfish or zooplankton. Zooplankton may include gametes, eggs, and larval forms of various invertebrate species, including corals. Although prolonged exposure to repeated playback of nearby impulsive sound (air guns) has resulted in developmental effects to larvae and eggs of some invertebrate species, brief exposure to a single or limited number of muzzle blasts or munition impacts would be unlikely to affect development. Other factors would limit the number and types of invertebrates potentially affected. Most squid are active near the surface at night, when weapons firing and launch occur infrequently. Weapons firing and launch typically occurs greater than 12 NM from shore, which because of the water depths would substantially limit the sound level reaching the bottom. Therefore, effects on benthic invertebrates (e.g., bivalve molluscs, worms, and crabs) are unlikely.

F.4.2 Explosive Stressors

F.4.2.1 Background

Explosions may affect invertebrates at the water surface, in the water column, or on the bottom. The potential for effects is influenced by typical detonation scenarios and invertebrate distribution. The majority of explosions would occur in the air or at the surface, with relatively few at the bottom (Appendix A, Navy Activity Descriptions), which would decrease the potential for effects on benthic invertebrate species. Surface explosions typically occur during the day at offshore locations more than 12 NM from shore. There is a general pattern of lower invertebrate abundance in offshore portions of the Study Area compared to relatively productive estuarine and nearshore waters. Therefore, the typical offshore location of detonations would result in fewer invertebrates potentially exposed to detonation effects. In addition, invertebrate abundances in offshore surface waters tend to be lower during the day, when surface explosions typically occur, than at night.

In general, an explosion may result in direct trauma and mortality due to the associated rapid pressure changes. For example, gas-containing organs such as the swim bladder in many fish species and the lungs of marine mammals are subject to rapid contraction and overextension (potentially causing rupture) when exposed to explosive shock waves. Most marine invertebrates lack air cavities and are therefore comparatively less vulnerable to damaging effects of pressure waves. A report summarizing the results of all known historical experiments (from 1907 to the 1980s) involving invertebrates and detonations concluded that marine invertebrates are generally insensitive to pressure-related damage from underwater explosions (Keevin & Hempen, 1997). Limited studies of crustaceans have examined mortality rates at various distances from detonations in shallow water (Aplin, 1947; Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Similar studies of molluscs have shown them to be more resistant than crustaceans to explosive effects (Chesapeake Biological Laboratory, 1948; Gaspin et al., 1976). Other invertebrates, such as sea anemones, polychaete worms, isopods, and amphipods, were observed to be undamaged in areas near detonations (Gaspin et al., 1976). Data from these experiments were used to develop curves that estimate the distance from an explosion beyond which at least 90 percent of certain adult benthic marine invertebrates would survive, depending on the weight of the explosive (Young, 1991) (Figure F-3). For example, 90 percent of crabs would survive a 200-lb. explosion if they are greater than about 350 ft. from the source, and shrimp, lobster, and oysters are less sensitive (i.e., greater survivability) to underwater explosions than crabs. Similar information on the effects of explosions to planktonic invertebrates and invertebrate larvae is not available.



Source: Young (1991)

Figure F-3: Prediction of Distance to 90 Percent Survivability of Marine Invertebrates Exposed to an Underwater Explosion

Charges detonated in shallow water or near the bottom, including explosive munitions disposal charges and some explosions associated with mine warfare, could kill and injure marine invertebrates on or near the bottom, depending on the species and the distance from the explosion. Taxonomic groups typically associated with the bottom, such as sponges, marine worms, crustaceans, echinoderms, corals, and molluscs, could be affected. Net explosive weight (NEW) for activities involving detonations on or near the bottom is relatively low. Most detonations occurring on or near the bottom would have a NEW of 60 lb. or less, although some explosives would be up to 1,000 lb. NEW. Based on the estimates shown on Figure 3.4-1, most benthic marine invertebrates beyond approximately 275 ft. from a 60 lb. blast would survive. The potential mortality zone for some taxa (e.g., shrimp, lobsters, worms, amphipods) would be substantially smaller. A blast near the bottom could disturb sessile invertebrates such as mussels and hard substrate suitable for their colonization. A blast in the vicinity of hard corals could cause direct effects on coral polyps or early life-stages of pre-settlement corals, or fragmentation and siltation of the corals. For example, in one study, moderate to substantial recovery from a single small blast directly on a reef was observed within five years, but reef areas damaged by multiple blasts showed no evidence of recovery during the six-year observation period (Fox & Caldwell, 2006). In another study, modeling results indicated that deep-water corals off Alaska damaged by trawling activities could require over 30 years to recover 80 percent of the original biomass (Rooper et al., 2011). The extent of trawling damage is potentially greater than that associated with detonations due to the small footprints of detonations compared to the larger surface area typically affected by trawling, as well as the avoidance of known shallow-water coral reefs and live hard bottom habitat during activities involving detonations. While the effects of trawling activities and underwater detonations are not directly comparable, the trawling model results illustrate the extended recovery time that may be required for deep-water coral regrowth following physical disturbance.

Effects on benthic invertebrates in deeper water would be infrequent because most offshore detonations occur in the air or at the surface. Benthic invertebrates in the abyssal zone (generally considered to be deeper than about 6,000 ft.) seaward of the coastal large marine ecosystems are sparsely distributed and tend to be concentrated around hydrothermal vents and cold seeps. These topographic features are typically associated with steep or high-relief areas of the continental shelf break (e.g., canyons, outcrops) or open ocean (e.g., seamounts).

Underwater surveys of a Navy bombing range in the Pacific Ocean (Farallon De Medinilla) were conducted annually from 1999 to 2012 (Smith & Marx, 2016). Although Farallon De Medinilla is a land range, bombs and other munitions occasionally strike the water. A limited number of observations of explosion-related effects were reported, and the results are summarized here to provide general information on the types of effects that may occur. However, the effects are not presumed to be broadly applicable to Navy training and testing activities. During the 2010 survey, it was determined that a blast of unknown size (and therefore of unknown applicability to proposed training and testing activities) along the waterline of a cliff ledge caused mortality to small oysters near the impact point. Corals occurring within 3 m of the affected substrate were apparently healthy. A blast crater on the bottom that was 5 m in diameter and 50 cm deep, presumably resulting from a surface detonation, was observed during one survey in water depth of 12 m. Although it may be presumed that corals or other invertebrates located within the crater footprint would have been damaged or displaced, evidence of such effects was not detected. The blast occurred in an area of sparse coral coverage and it is therefore unknown whether coral was present in the crater area prior to the blast.

The applicability of the mortality distance estimates shown on Figure 3.4-1 in Section 3.4 to invertebrates located in the water column is unknown. However, detonations that occur near the surface release a portion of the explosive energy into the air rather than the water, reducing effects on invertebrates in the water column. In addition to effects caused by a shock wave, organisms in an area of cavitation that forms near the surface above a large underwater detonation could be killed or injured. Cavitation is where the reflected shock wave creates a region of negative pressure followed by a collapse, or water hammer (see Appendix D, Acoustic and Explosive Concepts Supporting Information). The number of organisms affected by explosions at the surface or in the water column would depend on the size of the explosive, the distance of organisms from the explosion, and the specific geographic location within the Study Area. As discussed previously, many invertebrates that occur near the surface at night (e.g., squid and zooplankton) typically move down in the water column during the day, making them less vulnerable to explosions when most Navy activities involving detonations occur.

Marine invertebrates beyond the range of mortality or injurious effects may detect the impulsive sound produced by an explosion. At some distance, impulses lose their high pressure peak and take on characteristics of non-impulsive acoustic waves. Invertebrates that detect impulsive or non-impulsive sounds may experience stress or exhibit behavioral reactions in response to the sound. Repetitive impulses during multiple explosions, such as during a surface firing exercise, may be more likely to cause avoidance reactions. However, the distance to which invertebrates are likely to detect sounds is limited due to their sensitivity to water particle motion caused by nearby low-frequency sources. Sounds produced in water during training and testing activities, including activities that involve multiple impulses, occur over a limited duration. Any auditory masking, in which the sound of an impulse could prevent detection of other biologically relevant sounds, would be very brief.

F.4.3 Energy Stressors

F.4.3.1 Effects from In-Water Electromagnetic Devices

Several different types of electromagnetic devices are used during training and testing activities. Information on the types of activities that use in-water electromagnetic devices is provided in Appendix B (Activity Stressor Matrices).

Little information is available regarding marine invertebrates' susceptibility to electromagnetic fields. Magnetic fields are not known to control spawning or larval settlement in any invertebrate species. Existing information suggests sensitivity to electric and magnetic fields in at least three marine invertebrate phyla: Mollusca, Arthropoda, and Echinodermata (Bureau of Ocean Energy Management, 2011; Lohmann & Lohmann, 2006; Lohmann et al., 1995). A possible magnetic sense has been suggested in jellyfish as well, although this has not been demonstrated experimentally (Fossette et al., 2015). Much of the available information on magnetic field sensitivity of marine invertebrates pertains to crustaceans. For example, a magnetic compass sense has been demonstrated in the spiny lobster (*Panulirus argus*) (Lohmann & Lohmann, 2006; Lohmann et al., 1995), and researchers suggest subtle behavioral response to magnetic fields of about 1 millitesla (1,000 microtesla) in the Dungeness crab and American lobster (Woodruff et al., 2013). A review of potential effects of undersea power cables on marine species provides a summary of numerous studies of the sensitivity of various invertebrate species to electric and magnetic fields (Bureau of Ocean Energy Management, 2011). Electric field sensitivity is reported in the summary for only two freshwater crayfish species, while magnetic field sensitivity is reported for multiple marine invertebrate species, including molluscs, crustaceans, and echinoderms. Sensitivity thresholds range from 300 to 30,000 microtesla, depending on the species. Most responses consisted of behavioral changes, although non-lethal physiological effects were noted in two sea urchin species in a 30,000 microtesla field (embryo development) and a marine mussel exposed to 300 to 700 microtesla field strength (cellular processes). Marine invertebrate community structure was not affected by placement of energized underwater power cables with field strengths of 73 to 100 microtesla (Love et al., 2016). Effects to eggs of the sea urchin *Paracentrotus lividus* and to brine shrimp (*Artemia* spp.) cysts have been reported at relatively high magnetic field strengths (750 to 25,000 microtesla) (Ravera et al., 2006; Shckorbatov et al., 2010). The magnetic field generated by the Organic Airborne and Surface Influence Sweep (a typical electromagnetic device used in Navy training and testing) is about 2,300 microtesla at the source. Field strength drops quickly with distance from the source, decreasing to 50 microtesla at 4 m, 5 microtesla at 24 m, and 0.2 microtesla at 200 m from the source. Therefore, temporary disruption of navigation and directional orientation is the primary effect considered in association with magnetic fields.

Studies of the effects of low-voltage direct electrical currents in proximity to marine invertebrates suggest a beneficial effect on at least some species at appropriate current strength. American oysters (*Crassostrea virginica*) and various stony and soft corals occurring on substrates exposed to low-voltage currents (between approximately 10 and 1,000 microamperes) showed increased growth rates and survival (Arifin et al., 2012; Goreau, 2014; Jompa et al., 2012; Shorr et al., 2012). It is theorized that the benefits may result from a combination of more efficient uptake of calcium and other structure-building minerals from the surrounding seawater, increased cellular energy production, and increased pH near the electrical currents. The beneficial effects were noted in a specific range of current strength; higher or lower currents resulted in either no observable effects or adverse effects. The moderate voltage and current associated with the Organic Airborne and Surface Influence Sweep are not expected to result in adverse effects to invertebrates. In addition, due to the short-term, transient nature of electromagnetic device use, there would be no beneficial effects associated with small induced electrical currents in structures colonized by invertebrates.

F.4.4 Physical Disturbance and Strike Stressors

Most marine invertebrate populations extend across wide areas containing hundreds or thousands of discrete patches of suitable habitat. Sessile invertebrate populations may be connected by complex currents that carry adults and young from place to place. Effects on such widespread populations are difficult to quantitatively evaluate in terms of Navy training and testing activities that occur intermittently and in relatively small patches in the Study Area. Invertebrate habitats generally cover enormous areas (Section 3.2, Sediments and Water Quality) and, in this context, a physical strike or disturbance would affect individual organisms directly or indirectly, but not to the extent that viability of populations of common species would be affected. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential effects would be amplified for those invertebrate species or taxa with limited spatial extent. Examples of such organisms include abalones, stony corals, and sponges, which are mostly restricted to hard bottom habitat or artificial habitat. Shallow-water coral reefs, precious coral beds, live hard bottom, and other areas of hard substrate such as artificial reefs are protected to the extent they are included in current mitigation measures.

With few exceptions, activities involving vessels and in-water devices are not intended to contact the bottom due to potential damage to equipment and the resulting safety risks for vessel personnel. The potential for strike impact and disturbance of benthic or habitat-forming marine invertebrates would result from amphibious activities, bottom-crawling unmanned underwater vehicles, military expended materials, seafloor devices, and pile driving. For environmental and safety reasons, amphibious landings and other nearshore activities would avoid areas where corals are known to occur.

With the exception of habitat-forming benthic taxa (e.g., corals, sea pens, and sponges), most small invertebrate populations recover quickly from non-extractive disturbance. Many large invertebrates, such as crabs, shrimps, and clams, undergo massive disturbance during commercial and recreational harvests, storms, or beach restoration activities. Invertebrates that occur in the high-energy surf zone are typically resilient to dynamic processes of sediment erosion and accretion, although some community effects may occur due to rapid and relatively large-scale changes such as those associated with beach renourishment projects (U.S. Army Corps of Engineers, 2001).

Biogenic habitats such as shallow coral reefs, deep-water coral, and sponge communities may take decades to regrow following a strike or disturbance (Jennings & Kaiser, 1998; Precht et al., 2001). However, bottom-disturbing activities are not conducted on mapped coral reefs or live hard bottom. In soft bottom areas, recovery of benthic invertebrate populations after substantial human disturbance depends on factors such as size of the area disturbed, bottom topography, hydrodynamics of the affected area, seasonality of the disturbance, and the size and typical growth rate of affected species. Most studies of the effects of beach sand nourishment projects (which is a proxy for effects due to amphibious landings) have reported initial declines in benthic invertebrate populations due to burial and increased turbidity (which may affect filter-feeding capability), but subsequent recovery over time scales of weeks to years (Posey & Alphin, 2002; U.S. Army Corps of Engineers, 2001, 2012; Wilber et al., 2009). Recovery is typically greatest at nourishment sites when there is a close match in grain size between the existing and supplied sediment. However, species composition may be altered in the recolonized area, and overall invertebrate biomass may not recover for many years. Researchers found that trawling off the California coast resulted in no statistical difference in the abundance of sessile or mobile benthic invertebrates (Lindholm et al., 2013). However, repeated and intense bottom fishing disturbance can result in a shift from communities dominated by relatively high-biomass individuals towards dominance by high abundance of small-sized organisms (Kaiser et al., 2002). If activities are repeated at the same site, the benthic invertebrate community composition could be altered over time (years), especially for sessile invertebrates (e.g., coral). Some bottom-disturbing activities, such as mine countermeasures and neutralization training and testing, precision anchoring, and pile driving associated with the Port damage repair activity, may occur in the same locations or near the same locations yearly.

F.4.4.1 Effects from Vessels and In-Water Devices

Vessels

The majority of the training and testing activities under all the alternatives involve vessels. For a discussion of the types of activities that use vessels and where they are used, refer to Appendix B (Activity Stressor Matrices). See Table 3.0-14 for a representative list of Navy vessel types, lengths, and speeds.

Vessels could affect adults and other life stages of marine invertebrates by directly striking organisms, or by disturbing the water column or sediments (Bishop, 2008). Species that occur at or near the surface (e.g., jellyfish, squid) would potentially be exposed to direct vessel strikes. Exposure to propeller-generated turbulence was found to result in mortality in a zooplankton species (the copepod *Acartia tonsa*) located near the surface (Bickel et al., 2011). However, many pelagic invertebrates such as squid and zooplankton move away from the surface during the day, reducing potential exposures during daytime vessel operations. Many vessel hulls have a hydrodynamic shape, and pelagic marine invertebrates are therefore generally disturbed, rather than struck, as the water flows around a vessel. Zooplankton are ubiquitous in the water column and typically experience high mortality rates.

In addition, vessel hull strikes and propeller cavitation and turbulence could displace, damage, injure, or kill invertebrate eggs and larvae in the upper portion of the water column throughout the Study Area. For example, turbulent water was found to decrease successful fertilization and resulted in abnormal development and low survival in eggs of the broadcast spawning purple sea urchin (*Strongylocentrotus purpuratus*) (Mead & Denny, 1995). In some areas of the Hawaii Study Area, vessels could transit through water containing coral gametes, eggs, embryonic stages, or planula larvae of broadcast spawning species. Eggs of cluster coral (*Acropora millepora*) were found to disintegrate into irregular groups or individual blastomeres when subjected to even very light shearing forces and turbulence (Heyward & Negri, 2012). Such dissociation can be beneficial through creation of more juveniles, but may also cause mortality. Early embryonic development of broadcast spawning coral species has reportedly been affected by handling of captive-reared embryos (Guest et al., 2010). Although the available information indicates that developmental stages of numerous invertebrate species could be physically affected, broadcast-spawning invertebrates produce very large numbers of eggs and planktonic larvae that typically experience high mortality rates under normal conditions (Nybakken, 1993). Any effects resulting from Navy vessel operation would be biologically insignificant by comparison.

Propeller wash (water displaced by propellers used for propulsion) of even the deepest draft vessels operated over the continental shelf is likely indistinguishable from the water motion associated with periodic storm events, and vessel operation in deeper waters beyond the shelf break would not affect the bottom. Therefore, the potential for vessels to disturb invertebrates on or near the bottom would occur mostly during nearshore and inshore training or testing activities, and along dredged navigation channels. Invertebrates on or near the bottom in such relatively shallow areas could be affected by sediment disturbance or direct strike during amphibious landings. Few sources of information are available on the effect of non-lethal chronic vessel disturbance to marine invertebrates. One study of seagrass-associated marine invertebrates, such as amphipods and polychaetes, found that chronic disturbance from vessel wakes resulted in the long-term displacement of some marine invertebrates from the affected shallow-water area (Bishop, 2008). However, invertebrates that typically occur in areas associated with nearshore or inshore activities, such as shorelines, are highly resilient to vessel disturbance. They are regularly disturbed by natural processes such as high-energy waves and longshore currents, and generally recover quickly. Potential exceptions include sessile or encrusting invertebrates that may occur along sheltered shorelines that are subject to a high frequency of boat propeller- or wake-induced erosion (Grizzle et al., 2002; Zabawa & Ostrom, 1980). Increased erosion of shoreline banks or suspension of bottom sediments may cause turbidity that affects filter-feeding invertebrates. The results of a small number of studies suggest that the wave energy resulting from boat wakes produced in relatively narrow water bodies may affect oyster occurrence, and studies of shallow freshwater areas found that waves generated from small boats caused about 10 percent of benthic invertebrates (e.g., amphipods) to become suspended in the water column where they presumably would be more vulnerable to predation (Bilkovic et al., 2017).

Non-amphibious vessels avoid contact with the bottom in order to prevent damage to the vessels and benthic habitat that supports encrusting organisms. The encrusting organisms (e.g., hard corals) living on hard substrate in the ocean are exposed to strong currents under natural conditions and would not likely be affected by propeller wash. Many activities occur in offshore areas and, therefore, would be unlikely to affect benthic invertebrates, although small-caliber gunnery exercises, blank firing, and smoke grenade use may occur in areas closer to shore. Many Navy vessel movements in nearshore waters are concentrated in established channels and ports or predictable transit corridors between the Hawaiian Islands or between San Diego Bay and SCI, and shallow-water vessels typically operate in defined boat lanes with sufficient depths to avoid propeller or hull strikes on the bottom.

The only source of shallow-water vessel movement in the Study Area with known direct effects on benthic invertebrates is amphibious landings, which are conducted in the Hawaii Study Area and California Study Area (Appendix A, Navy Activity Descriptions). Amphibious vessels would contact the bottom in the surf zone during amphibious assault and amphibious raid operations. Benthic invertebrates of the surf zone, such as crabs, clams, and polychaete worms, within the disturbed area could be displaced, injured, or killed during amphibious operations. Burrowing species such as ghost shrimp are present on many beaches, and individuals in relatively shallow burrows located just above harder sand layers could be injured or killed if amphibious vessels compress the sand above them. Passage of amphibious vessels could cause some elevated turbidity in the nearshore zone seaward of the surf zone. However, the sediment along landing beaches is constantly being reworked by nearshore wave energy and, to a lesser extent (although more frequently than disturbance caused by amphibious landings), storm events. Benthic invertebrates inhabiting these areas are adapted to a naturally disturbed environment and are expected to rapidly re-colonize similarly disturbed areas by immigration and larval recruitment. Studies indicate that benthic communities of high-energy sandy beaches recover relatively quickly (typically within two to seven months) following beach nourishment. Researchers found that the macrobenthic (visible organisms on the bottom) community required between 7 and 16 days to recover following excavation and removal of sand from a 200 square meter quadrant from the intertidal zone of a sandy beach (Schoeman et al., 2000). The number of invertebrates affected during amphibious landings would be small compared to the number that are affected during activities such as beach nourishment. The effects of amphibious vehicle operations on benthic communities would therefore likely be minor, short term, and local.

Other than organisms occurring at amphibious landing sites, invertebrates that occur on the bottom, including shallow-water corals, organisms associated with hard bottom, and deep-water corals, are not likely to be exposed to vessel strikes. Propeller movement has the potential to disrupt sediments that could affect shallow-water corals and hard bottom communities. However, shallow-water corals and abalone species do not occur along the shoreline adjacent to amphibious landing areas.

In-Water Devices

Some of the training and testing activities under both action alternatives involve the use of in-water devices, including remotely operated vehicles, unmanned surface vehicles, unmanned underwater vehicles, motorized autonomous targets, and towed devices. For a discussion of the types of activities that use in-water devices, see Appendix B (Activity Stressor Matrices). See Table 3.0-16 in Section 3.0 for the types, sizes, and speeds of representative Navy in-water devices used in the Study Area.

In-water devices can operate from the water's surface to the benthic zone. The devices could potentially affect marine invertebrates by directly striking organisms or by disturbing the water column. As discussed for vessel use, most invertebrates in the water column would be disturbed, rather than struck, as water flows around a device due to the hydrodynamic shape. In addition, in-water devices are smaller than most Navy vessels, decreasing the surface area in which invertebrates could be struck. The potential for direct strike is reduced for some types of devices because they are operated at relatively low speeds (e.g., unmanned underwater vehicles, which are typically operated at speeds of 1 to 15 knots). Unmanned surface vehicles are operated at the greatest speeds (up to 50 knots or more) and therefore have greater potential to strike invertebrates. However, relatively few invertebrates occur at the surface and consist mostly of squid, jellyfish, and zooplankton. Squid and many zooplankton species move away from the surface during the day (Nybakken, 1993), when unmanned surface vehicles are typically operated. In-water devices do not normally collide with invertebrates on the bottom because the devices are operated in relatively deep water and contact with the bottom is avoided. Devices operated very near the bottom could potentially disturb sediments and associated invertebrates through propeller wash. However, such disturbance would be infrequent and would affect a small area, and disturbed areas would be quickly reoccupied by benthic invertebrates.

As discussed for vessels, zooplankton and invertebrate eggs and larva could be displaced, damaged, injured, or killed by propeller wash or turbulence resulting from water flow around in-water devices. Effects due to turbulence would generally increase with increasing speed of the device. Many zooplankton species migrate away from the surface during the day, when Navy training and testing typically are conducted, decreasing the potential for effects in the upper portions of the water column. The number of individuals affected would be small in comparison to overall populations, and the affected species generally exhibit rapid growth and recovery rates.

F.4.4.2 Effects from Military Expended Materials

Military expended materials are deposited throughout the Study Area. However, the majority of military expended materials are deposited within established range complexes and testing ranges. These areas of higher military expended materials deposition are generally located away from the coastline on the continental shelf and slope and beyond (e.g., abyssal plain). Physical disturbance or strikes by military expended materials on marine invertebrates is possible at the water's surface, through the water column, and on the bottom. However, disturbance or strike effects on marine invertebrates by military expended materials falling through the water column are not very likely because military expended materials do not generally sink rapidly enough to cause strike injury. Exposed invertebrates would likely experience only temporary displacement as the object passes by. Therefore, the discussion of military expended materials disturbance and strikes will focus on items at the water's surface and on the bottom.

Potential effects on invertebrates generally consist of physical trauma, stress or behavioral responses, abrasion, and shading. Military expended materials may injure or kill invertebrates by directly striking individuals, causing breakage (particularly for species with exoskeletons or that build structures), crushing, or other physical trauma. Direct strike may result from the initial impact, or may occur after items fall through the water column and settle onto invertebrates or are moved along the bottom by water currents or gravity. Expended items may also bury or smother organisms although, depending on the size of the expended item relative to the animal, some mobile invertebrates may be able to move or dig out from underneath an item. In addition to physical strike, military expended materials may disturb individuals and cause them to change locations, behaviors, or activities. Disturbance could therefore result in effects such as briefly increased energy expenditure, decreased feeding, and increased susceptibility to predation. Expended items could also cause increased turbidity that could affect filter-feeding species, although such effects are likely to be localized and temporary. Expended items that come to rest on or near corals could cause abrasion or shading (in the case of corals that host symbiotic algae) that reduces photosynthesis in the algae, although these effects are unlikely based on the mitigation measures in place for shallow-water coral reefs where symbiotic algae are present. Abrasion refers to scraping or wearing down of a supporting structure or hard body part (e.g., coral skeleton, shell) through repeated impact on the same individual or structure. Abrasion would generally be associated with military expended materials such as flexible materials (e.g., wires or cords) that become fixed in a location for some time but that are moved repeatedly over sessile invertebrates by water currents.

Military expended materials that impact the water surface could directly strike zooplankton, the gametes, embryos, and larvae of various invertebrate species (including ESA-listed abalone species), and a small number of adult invertebrates (e.g., squid, jellyfish, swimming crabs). However, many zooplankton and squid are absent from the surface water column during the day when most training and testing activities occur. Inert military expended materials also have the potential to impact the water and produce a large impulse which could disturb nearby invertebrates. Potential effects on invertebrates resulting from impulsive sound and shock waves are discussed in Section 3.4.3.1 (Acoustic Stressors) and Section 3.4.3.2 (Explosive Stressors). In addition to direct strike of invertebrates and production of impulsive sound, surface water impacts could affect physical properties of the surrounding water (e.g., slight heating or increased dissolved gas concentrations due to turbulent mixing with the atmosphere), potentially affecting the suitability of the affected water mass as habitat for some invertebrate species. However, physical changes to the water column would be localized and temporary, persisting for only a few minutes.

Compared to surface waters and offshore areas, a greater number of macroinvertebrates typically occurs on the bottom and closer to shore. Benthic invertebrate taxa, including sponges, cnidarians, worms, bryozoans, molluscs, arthropods, and echinoderms, may occur in areas affected by military expended materials. However, some of the most sensitive benthic species (e.g., corals) are more likely to occur on hard bottom, reefs, and other hard substrates. Shallow-water coral reefs are protected by mitigation measures from most activities that generate military expended materials. Military expended materials that impact the bottom may affect invertebrates by strike (including injury or mortality), disturbance, burial, abrasion, or shading within the footprint of the item (the area of substrate physically covered by the item). Military expended materials may also cause physiological or behavioral reactions to individual invertebrates outside the footprint of the items. After items come to rest on the bottom, continued impacts are possible if the items are mobilized by currents or waves and damage benthic invertebrates as they move. Turbidity may also occur as water flows around deposited items. However, these impacts would generally cease when the military expended materials are incorporated into the seafloor by natural encrustation or burial processes, or become otherwise immobilized.

Sessile marine invertebrates and infauna (organisms attached to the bottom or living in the sediments) are generally more susceptible to military expended material disturbance and strike than benthic species with the ability to move relatively quickly over the bottom. Some susceptible species (e.g., hydroids, sponges, soft corals) have fragile structures and sensitive body parts that could be damaged or covered by military expended materials. Military expended materials could also break hard structures such as coral skeletons and mussel beds. Shallow- and deep-water corals that build complex or fragile structures could be particularly susceptible to breakage or abrasion. Such structures are resistant to physical forces typical of ambient conditions (e.g., water currents), but not as resilient to other types of physical disturbance involving greater force. Decelerators/parachutes would be unlikely to be carried by currents onto reef structures due to the typical offshore locations of use and the sink rate of the items. Expended items may provide new colonization sites for benthic invertebrates. Researchers found that military expended materials in a bombing range became covered by sedentary reef invertebrates over time (Smith & Marx, 2016). However, invertebrate species composition on artificial substrates may differ from that of the surrounding natural community.

Potential effects on shallow-water corals, invertebrates associated with hard bottom habitat, or deep-water corals present the greatest risk of long-term damage compared with other bottom communities because: (1) many corals and hard bottom invertebrates are sessile, fragile, and particularly vulnerable; (2) many of these organisms grow slowly and could require decades to recover; and (3) military expended materials are likely to remain exposed on hard bottom communities whereas shifting sediment patterns would tend to bury military expended materials in soft bottom communities. The probability of striking deep-water corals or invertebrates located on hard bottom habitat is low, given their low percent cover on suitable habitat (see Section 3.5.2.2, Bottom Habitats, for a discussion of hard bottom habitat).

A few investigations have been conducted to determine the presence and, in some cases, possible effects of military expended materials on the bottom. The results of multi-year underwater surveys at a military bombing range in the Mariana Archipelago (Pacific Ocean) provide an example of potential effects resulting from expended munitions. Water areas were not targeted at this range; bottom effects occurred only when the target land mass was missed or the munition bounced off the land into the water. The surveys found no overall long-term adverse effects on corals or other invertebrates due to expended items, despite several decades of use (Smith & Marx, 2016). Numerous intact bombs and fragments were observed on the bottom. Inert 500 lb. bombs were found to disturb a bottom area of 17 square meter each, although specific damage to invertebrates, if any, was not described. It may be presumed that invertebrates within this footprint could have been killed, injured, damaged, or displaced. Expended items, once settled in place, appeared to become encrusted with marine growth and pose no substantial long-term threat to invertebrates. The condition of corals indicated a healthy environment, with no apparent change in species composition, distribution, size, or stress indicators. However, the results of several other studies indicate that sessile invertebrate communities growing on artificial substrate such as the expended munitions are often different than those growing on natural substrate (Burt et al., 2009; Macreadie et al., 2011; Perkol-Finkel et al., 2006; Steimle & Zetlin, 2000). A remotely operated vehicle survey of deep portions of the Jacksonville Range Complex reported only two exposed items of military expended materials in about 37,800 m of survey line distance (U.S. Department of the Navy, 2010a, 2011). However, it is important to note that the survey was not designed to document military expended materials and these were only the items photographed using still frames. Another extensive remotely operated vehicle survey along the continental shelf break and canyons in the northeast and mid-Atlantic region found marine debris in 81 percent of individual dives, but the items did not include any visible military expended materials (Quattrini et al., 2015). Underwater surveys of bottom areas off the Gulf coast of Florida with a presumably high potential for military expended materials (based on reported obstructions by fishermen) found no items of military origin, suggesting that expended materials may be widely distributed or may become covered by sediments (U.S. Department of the Navy, 2013c). In a deep-sea trawl survey of the northern Gulf of Mexico, items of military origin were found (artillery shells and a missile), but were among the least-frequently encountered types of debris (Wei et al., 2012).

Military Expended Materials - Munitions

Military expended materials that are munitions and associated with training activities include small-, medium-, and large-caliber projectiles, bombs, missiles, rockets, and grenades. Fragments of exploded munitions are also included because they can result in effects on invertebrates that are similar to those associated with smaller intact munitions. Military expended materials associated with testing activities are the same except that there are no grenades. Navy training and testing activities in the Study Area include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including small-, medium-, and large-caliber projectiles. Large-caliber projectiles are primarily used in the open ocean beyond 20 NM from shore. Direct strike from bombs, missiles, and rockets would result in types of effects similar to those of projectiles. However, they are larger than most projectiles and are likely to produce a greater number of fragments. Bombs, missiles, and rockets are designed to explode within about 3 ft. of the sea surface, where marine invertebrates larger than zooplankton are relatively infrequent.

Military Expended Materials Other Than Munitions

Military expended materials other than munitions associated with training and testing activities include a large number of items such as aerial countermeasures, targets (surface and aerial), mine shapes, ship hulk, decelerators/parachutes, acoustic countermeasures, sonobuoys, and other materials such as torpedo accessories, concrete slugs, marine markers, bathythermographs, endcaps, and pistons. Some expended materials used during training and testing activities, including some types of torpedoes and targets, non-explosive mine shapes, and bottom-placed instruments, are recovered.

Chaff, which consists of aluminum-coated glass fibers, may be transported great distances by the wind, beyond the areas where they are deployed, before contacting the sea surface. These materials contact the sea surface and bottom with very little kinetic energy, and their low buoyant weight makes them an inconsequential strike and abrasion risk. Therefore, chaff is not considered to be a potential strike and disturbance stressor.

During a sinking exercise, aircraft, ship, and submarine crews deliver munitions on a surface target, which is a clean, deactivated ship that is deliberately sunk using multiple weapon systems. Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes. Habitat-forming invertebrates are likely absent where sinking exercises are planned because the activity occurs in depths greater than the range for shallow-water and many deep-water coral species (approximately 3,000 m) and away from typical locations for hydrothermal vent or cold seep communities (e.g., seamounts) (Cairns, 2007). It is unlikely that deep-sea hard corals would be affected by a sinking ship hulk or fragments of a hulk due to their lack of occurrence below depths of about 3,000 m (the depth of the aragonite saturation boundary; see Appendix C, Section 3.1.1, Habitat Use).

Decelerators/parachutes of varying sizes are used during training and testing activities and may be deployed from aircraft or vessels. Similar to other marine debris such as derelict fishing gear, decelerators/parachutes may kill or injure sessile benthic invertebrates due to covering/shading or abrasion. Activities that expend sonobuoy and air-launched torpedo decelerators/parachutes generally occur in relatively deep water away from the shore; however, there is some potential for near shore effects from testing events using sonobuoys to conduct mine detection in near shore environments. Decelerators/parachutes expended over deep offshore areas may affect deep-water invertebrates (particularly sessile species) by disturbance, strikes, burial, smothering, or abrasion. For example, a decelerator/parachute could cover a sponge or deep-water coral and impair feeding.

Proportional affect analysis determined that the total bottom area affected by all military expended materials in all training areas would be about 145 acres annually, ranging from less than 1 acre to about 120.5 acres in specific range complexes and substrate types. This represents much less than 1 percent of available bottom habitat in any range complex. In addition to expended items, recovered materials would temporarily disturb approximately 10 acres of bottom habitat in all training areas combined. The substrate types and associated invertebrate assemblages within the potentially disturbed areas are difficult to predict, as discussed in Appendix I (Military Expended Materials and Direct Strike Impact Analyses). Activities conducted throughout the Study Area have the potential to affect hard bottom communities as well as invertebrates within all other habitat types. Activities occurring at depths of less than about 3,000 m may affect deep-water corals. Consequences could include damage, injury, or mortality as a result of projectiles, munitions, or other items. Decelerators/parachutes, wires, and cables could also affect benthic communities if they are mobilized by water currents, although it is expected that most such materials would become buried, encrusted, or otherwise immobilized over time and would not continue to affect individual invertebrates or invertebrate assemblages. Effects would be most pronounced if all the materials expended within the applicable depth range were deposited on areas of hard substrate supporting long-lived, sessile organisms such as deep-water corals, because it may be assumed that many of the benthic invertebrates present in the impact area footprint would be killed, injured, displaced, or disturbed by the expended materials. In addition, some previously undisturbed bottom area would be affected by activities in subsequent years. Conversely, effects would be less if the materials were deposited on soft bottom areas containing invertebrate communities that recover relatively quickly from disturbance. Although hard substrate potentially supporting deep-water corals and other invertebrate communities is present in at least some areas in water depths less than 3,000 m, a scenario of all expended materials being deposited on such substrate is unrealistic. Deep-water stony corals are relatively rare in the Hawaiian Archipelago region, and most species are solitary. Hard and mixed bottom types, which support the occurrence of deep-water corals other than sea pens, are relatively rare off the U.S. west coast, accounting for about 10 percent of the substrate from the shelf to depths of 3,000 m (Clarke et al., 2015). These habitat types are often associated with seamounts, banks, and canyons (particularly banks in the Channel Islands region). Based on the results of limited investigation, a low percentage of available hard substrate may be inhabited by deep-water corals or other invertebrate species (Harter et al., 2009; U.S. Department of the Navy, 2010a). It is expected that most of the bottom type affected would be soft substrate (Appendix I, Military Expended Materials and Direct Strike Impact Analyses). Therefore, although it is possible for a portion of expended items to affect hard substrate and associated sensitive invertebrate communities, the number of exposed individuals would not likely affect the overall viability of populations or species. While the potential for overlap between Navy activities and invertebrates is reduced for those species living in rare habitats, if overlap does occur, any potential effects would be amplified for those invertebrate species or taxa with limited spatial extent. With the exception of abalones and some shallow-water corals, detailed distribution and habitat utilization information sufficient to support species-specific analysis is generally unavailable.

F.4.4.3 Effects from Seafloor Devices

For a discussion of the types of activities that use seafloor devices, where they are used, and how many activities would occur under each alternative, see Appendix B (Activity Stressor Matrices). Seafloor devices include items that are placed on, dropped on, or moved along the substrate for a specific purpose, and include mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom placed targets that are recovered (not expended). Placement or deployment of seafloor devices would cause disturbance, injury, or mortality to marine invertebrates within the footprint of the device. These items could potentially break hard substrate and associated biogenic habitats (e.g., hard coral skeletons). Objects placed on the bottom may attract invertebrates, or provide temporary attachment points for invertebrates. Some invertebrates attached to the devices would be removed from the water when the devices are recovered. A shallow depression may remain for some time in the soft bottom sediment where an anchor was dropped, potentially altering the suitability of the affected substrate for benthic invertebrates temporarily (possibly months).

Seafloor devices may also disturb marine invertebrates outside the footprint of the device, and would cause temporary (possibly hours to days) local increases in turbidity and sedimentation near the bottom, along with some changes in scouring/deposition patterns in higher current areas with soft bottom. Sedimentation can smother sessile invertebrates, while turbidity may affect respiratory organs or impair the ability of filter-feeding invertebrates to obtain food (e.g., by clogging their feeding structures or diluting the amount of food in the surrounding volume of water). However, the brief episodes of minor turbidity associated with Navy seafloor devices would be localized and the effects do not change the substrate type. Compared to overall populations, relatively few individuals would be affected.

Precision anchoring, and the associated potential effects, is qualitatively different than other seafloor devices because the activity involves repeated disturbance to the same soft bottom areas. Precision anchoring may result in temporary and localized disturbances to water column and bottom habitats. For example, an anchor may shift due to changing currents or vessel movement and the mooring chain may drag across the bottom, causing abrasion and effects on benthic species (Davis et al., 2016). Anchor impacts on the bottom would likely crush a small number of benthic invertebrates. Bottom disturbance would result in localized sedimentation and turbidity, which could smother invertebrates or affect respiration or feeding. Turbidity would quickly dissipate (i.e., minutes to hours) following the exercise, and many soft bottom invertebrates are burrowing organisms that would be unaffected by shallow burial. Although precision anchoring occurs in soft-bottom areas, where invertebrate populations are generally resilient to disturbance, invertebrates in designated anchorage areas may be prevented from fully recovering due to long-term use, and benthic composition may be changed compared to historical conditions.

F.4.5 Entanglement Stressors

This section analyzes the potential entanglement effects of the various types of expended materials used by the Navy during training and testing activities within the Study Area. Included are potential effects from wires and cables, and decelerators/parachutes. In this section, only potential effects of these items as entanglement stressors are discussed. Abrasion and covering/shading effects on sessile benthic invertebrates are discussed with physical effects in Section 3.4.3.3.3.2.1 (Effects from Military Expended Materials).

Marine invertebrates are likely less susceptible than vertebrates to entanglement, as illustrated by the fact that fishing nets which are designed to take pelagic marine invertebrates operate by enclosing or entrapping rather than entangling (Chuenpagdee et al., 2003). However, entanglement may be possible for some species and some expended items. A survey of marine debris entanglements found that marine invertebrates accounted for 16 percent of all animal entanglements (Ocean Conservancy, 2010). The same survey cites potential entanglement in military items only in the context of waste-handling aboard ships, and not for military expended materials. A summary of the effects of litter on various marine species identified potential effects on some invertebrate taxa, particularly mobile benthic species such as crabs and sea stars, that may become entangled in debris (e.g., nets) after attempting to move through the items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a). The potential for a marine invertebrate to become entangled in wires, cables, or decelerators/parachutes is considered remote. The materials generally do not have the characteristics required to entangle marine species. Wires and cables are essentially rigid lines. Sonobuoy components may include plastic mesh and a float unit. Although mesh items have increased potential for entangling marine animals in general, and invertebrates can become entangled in nets (Ocean Conservancy, 2010), invertebrates are not particularly susceptible to entanglement in these items. Decelerators/parachutes have large openings between the cords separating the decelerator/parachute fabric from the release mechanism. There is no plausible scenario in which decelerator/parachute cords would tighten around and hold a mobile invertebrate. Decelerators/parachutes sink slowly through the water column, although many have weights attached to their lines to speed their sinking. Invertebrates in the water column with limited mobility (e.g., jellyfish, zooplankton) could be trapped in decelerator/parachute fabric as it sinks. The potential effects of decelerators/parachutes covering sessile invertebrate species on the bottom is discussed in Section 3.4.3.4.2 (Decelerators/Parachutes).

F.4.5.1 Effects from Wires and Cables

Fiber-optic cables, torpedo guidance wires, sonobuoy wires, and expendable bathythermograph wires would be expended during training and testing activities. For a discussion of the types of activities that use wires and cables, see Appendix B (Activity Stressor Matrices).

A marine invertebrate could become temporarily entangled and escape unharmed, it could be held tightly enough that it could be injured during its struggle to escape, it could be preyed upon while entangled, or it could starve while entangled. The probability of these outcomes cannot be predicted because interactions between invertebrate species and entanglement hazards are not well known. However, it is unlikely that an invertebrate would become entangled in wires or cables. The items would be essentially linear after deployment, as they sink through the water column. Once the items reach the bottom, they could be moved into different shapes or loop around objects due to water currents, but the items are not expected to form tight coils, and the possibility of an invertebrate being ensnared is remote. Fiber-optic cables are relatively brittle and readily break if knotted, kinked, abraded against sharp objects, or looped beyond the items' bend radius of 3.4 millimeters. The wires and cables would eventually become buried in sediment or encrusted by marine growth, which would eliminate or further reduce the entanglement potential. The small number of items expended across the Study Area results in an extremely low rate of potential encounter for marine invertebrates.

F.4.6 Ingestion Stressors

This section analyzes the potential ingestion effects of the various types of military expended materials used by the Navy during training and testing activities within the Study Area, which may be broadly categorized as munitions and materials other than munitions. Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 1.5 (Conceptual Framework for Assessing Effects from Ingestion) of this appendix. The Navy expends the following types of materials that could become ingestion stressors during training and testing in the Study Area: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff and flares, chaff and flare accessories (including end caps, compression pads or pistons, and o-rings), and small decelerators/parachutes. Very few invertebrates are large enough to ingest intact small- and medium-caliber munitions and casings; potential effect resulting from these items would be limited to a few taxa such as squid and octopus. Other military expended materials such as targets, large-caliber projectiles, intact training and testing bombs, guidance wires, sonobuoy tubes, and marine markers are too large for any marine invertebrate to consume and are eliminated from further discussion.

Expended materials could be ingested by marine invertebrates in all large marine ecosystems and open ocean areas. Ingestion could occur at the surface, in the water column, or at the bottom, depending on the size and buoyancy of the expended object and the feeding behavior of the animal. Floating material is more likely to be eaten by animals that may feed at or near the water surface (e.g., jellyfish, squid), while materials that sink to the bottom present a higher risk to both filter-feeding sessile (e.g., sponges) and bottom-feeding animals (e.g., crabs). Most military expended materials and fragments of military expended materials are too large to be ingested by marine invertebrates, and relatively large predatory or scavenging individuals are unlikely to consume an item that does not visually or chemically resemble food (Koehl et al., 2001; Polese et al., 2015). Many arthropods such as blue crab (*Callinectes sapidus*) and spiny lobster are known to discriminate between palatable and unpalatable food items inside the mouth, so in a strict sense, only items that are passed into the interior digestive tract should be considered to be ingested (Aggio et al., 2012). If expended material is ingested by marine invertebrates, the primary risk is blockage in the digestive tract. Most military expended materials are relatively inert in the marine environment, and are not likely to cause injury or mortality via chemical effects (see Section 3.4.3.7, Secondary Stressors, for more information on the chemical properties of these materials). However, pollutants (e.g., heavy metals and PCBs) may accumulate on the plastic components of some military expended materials. Plastic debris pieces collected at various locations in the North Pacific Ocean had polycyclic aromatic hydrocarbons and pesticides associated with them (Rios et al., 2007). Relatively large plastic pieces could be ingested by some species. However, filter- or deposit-feeding invertebrates have the greatest potential to ingest small plastic items, and any associated pollutants could harm the individual animal or subsequently be incorporated into the food chain.

The potential for marine invertebrates to encounter fragments of ingestible size increases as the military expended materials degrade into smaller fragments over months to decades. Intact munitions, fragments of munitions, and other items could degrade into metal and plastic pieces small enough to be consumed by indiscriminate feeders, such as some marine worms. Deposit-feeding, detritus-feeding, and filter-feeding invertebrates such as amphipods, polychaete worms, zooplankton, and mussels have been found to consume microscale plastic particles (microplastics) that result from the breakdown of larger plastic items (National Oceanic and Atmospheric Administration Marine Debris Program, 2014c; Wright et al., 2013). Ingestion by these types of organisms is the most likely pathway for degraded military expended materials to enter the marine food web. Transfer of microplastic particles to higher trophic levels was demonstrated in one experiment (Setala et al., 2014). Ingestion of microplastics may result in physical effects such as internal abrasion and gut blockage, toxicity due to leaching of chemicals, and exposure to attached pollutants. Potentially harmful bacteria may also grow on microplastic particles (Kirstein et al., 2016). In addition, consumption of microplastics may result in decreased consumption of natural foods such as algae (Cole et al., 2013). Microplastic ingestion by marine worms was shown in one study to result in lower energy reserves (Wright et al., 2013). Microplastic ingestion has been documented in numerous marine invertebrates (e.g., mussels, worms, mysid shrimp, bivalve molluscs, zooplankton, and scleractinian corals (Cole et al., 2013; Hall et al., 2015; Setala et al., 2016; Wright et al., 2013). In an experiment involving pelagic and benthic marine invertebrates with different feeding methods, all species exposed to microplastic particles ingested some of the items (Setala et al., 2016). Deposit-feeding worms and an amphipod species ingested the fewest particles, while bivalves and free-swimming crustaceans ingested higher amounts. Ingestion of plastic particles may result in negative physical and chemical effects to invertebrates, although invertebrates are generally able to discharge these particles from the body. Overall population-level effects across a broad range of species are currently uncertain (Kaposi et al., 2014; Wright et al., 2013).

The most abundant military expended material of ingestible size is chaff. The materials in chaff are generally nontoxic in the marine environment except in quantities substantially larger than those any marine invertebrate would likely encounter as a result of Navy training and testing activities. Chaff fibers are composed of an aluminum alloy coating on glass fibers of silicon dioxide (Section 3.0.3.3.6.3, Military Expended Materials). Chaff is similar in form to fine human hair, and is somewhat analogous to the spicules of sponges or the siliceous cases of diatoms (U.S. Department of the Navy, 1999). Many invertebrates ingest sponges, including the spicules, without suffering harm (U.S. Department of the Navy, 1999). Marine invertebrates may occasionally encounter chaff fibers in the marine environment and may incidentally ingest chaff when they ingest prey or water. Literature reviews and controlled experiments suggest that chaff poses little environmental risk to marine organisms at concentrations that could reasonably occur from military training and testing (Arfsten et al., 2002; U.S. Department of the Navy, 1999). Studies were conducted to determine the effects of chaff ingestion on various estuarine invertebrates occurring near a site of frequent chaff testing in Chesapeake Bay (Schiff, 1977). American oysters (various life stages), blue crabs (*Callinectes sapidus*), blue mussels (*Mytilus edulis*), and the polychaete worm *Nereis succinea* were force fed a chaff-and-food mixture daily for a few weeks at concentrations 10–100 times the predicted exposure level in the Bay. Although some mortality occurred in embryonic oyster larvae from 0 to 48 hours, the authors suggest confounding factors other than chaff (e.g., contaminated experimental water) as the cause. The authors reported no statistically significant mortality or effects on growth rate for any species. Because many invertebrates (e.g., crabs, shrimp) actively distinguish between food and non-food particles, the experimental design represents an unrealistic scenario with respect to the amount of chaff consumed. An investigation of sediments in portions of Chesapeake Bay exposed to aluminized chaff release for approximately 25 years found no significant increase in concentration compared to samples collected 3.7 km from the release area (Wilson et al., 2002).

As described in Section 3.4.2 (Affected Environment), many thousands of marine invertebrate species inhabit the Study Area. Most available literature regarding the effects of debris ingestion on marine invertebrates pertains to microplastics (Goldstein & Goodwin, 2013; National Oceanic and Atmospheric Administration Marine Debris Program, 2014c; Wright et al., 2013). Discussion of potential consumption of larger items is typically focused on fishes, reptiles, mammals, and birds. Consequently, it is not possible to speculate in detail on which invertebrates in which locations might ingest all types of military expended materials. Despite the potential effects, it is reasonable to conclude that relatively large military expended materials would not be intentionally consumed by actively foraging invertebrates unless they are attracted by other cues (e.g., visual cues such as flashing metal bits that squid might attack). Passively-feeding invertebrates (e.g., shellfish, jellyfish) may accidently ingest small particles by filtration or incidental adhesion to sticky mucus. The potential for effects on invertebrates from ingestion of military expended materials is also related to the locations of Navy training and testing activities relative to invertebrate population densities. Increased invertebrate densities are associated with the highest densities of microscopic plant food, which are typically located in nearshore waters in closer proximity to nutrient sources or in areas where upwelling tends to occur. Conversely, activities that generate military expended materials occur mostly seaward of nearshore water. Small deposit-feeding, detritus-feeding, and filter-feeding invertebrates would be most likely to ingest small items such as degraded plastic particles, although lobsters reportedly may also ingest microplastics (National Oceanic and Atmospheric Administration Marine Debris Program, 2014c). Though ingestion is possible in some circumstances, due to the overall size and composition of military expended materials, effects on populations would likely not be detectable.

F.4.6.1 Effects from Military Expended Materials – Munitions

Ingestion of intact military expended materials that are munitions is not likely for most types of expended items because they are too large to be ingested by most marine invertebrates. Though ingestion of intact munitions or large fragments is conceivable in some circumstances (e.g., a relatively large invertebrate such as an octopus or lobster ingesting a small-caliber projectile), such a scenario is unlikely due to the animal’s ability to discriminate between food and non-food items. Indiscriminate deposit- and detritus-feeding invertebrates such as some marine worms could potentially ingest munitions fragments that have degraded to sediment size. Metal particles in the water column may be taken up by suspension feeders (e.g., copepods, mussels) (Chiarelli & Roccheri, 2014; Griscom & Fisher, 2004), although metal concentrations in the water are typically much lower than concentrations in sediments (Bazzi, 2014; Brix et al., 2012).

F.4.7 Secondary Stressors

This section analyzes potential effects on marine invertebrates exposed to stressors indirectly through effects on their habitat (sediment or water quality) or prey. The assessment of potential water and sediment quality stressors refers to previous sections (Section 3.2, Sediments and Water Quality), and addresses specific activities in local environments that may affect invertebrate habitats. The terms “indirect” and “secondary” do not imply reduced severity of environmental consequences, but instead describe how the effect may occur in an organism or its ecosystem. Stressors from Navy training and testing activities that could pose indirect effects on marine invertebrates via habitat or prey include: (1) explosives and explosive byproducts, (2) chemicals other than explosives, and (3) metals.

Secondary or indirect stressors may affect benthic and pelagic invertebrates, gametes, eggs, and larvae by changes to sediment and water quality. Physical and biological features of ESA-listed black abalone critical habitat are defined in Appendix H, Section 3.2.1.1 (Status and Management). These features are rocky substrate, food resources, juvenile settlement habitat, suitable water quality, and suitable nearshore circulation patterns. Exemptions from critical habitat designation include areas offshore of San Nicolas Island and SCI. However, exemption does not preclude analysis of ESA-listed black abalones. Potential effects to rocky substrate would be associated with physical effects such as breakage or covering. Potential effects to water quality would be associated with introduction of metal, plastic, or chemical substances into the water column.

Explosives and Explosive Byproducts

Secondary effects on invertebrates resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily but would resettle to the bottom. There would be no overall reduction in the surface area or volume of sediment available to benthic species that occur on the bottom or within the substrate. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges).

Explosions in the water column or on the bottom could affect invertebrate prey species. Some species of most invertebrate taxa prey upon other invertebrate species, with prey items ranging in size from zooplankton to relatively large shrimps and crabs. Therefore, in a strict sense, mortality to invertebrate species resulting from an explosion may represent a reduction in prey to other invertebrate species. A few invertebrates such as squid and some jellyfish prey upon fish, although jellyfish capture fish passively rather than through active pursuit. Therefore, fish mortality resulting from an explosion would reduce the number of potential prey items for invertebrates that consume fish. In addition to mortality, fish located near a detonation would likely be startled and leave the area, temporarily reducing prey availability until the affected area is repopulated.

Some invertebrates (e.g., worms, crustaceans, sea stars) are scavengers that would feed on any vertebrate or invertebrate animal that is killed or significantly impaired by an explosion. Therefore, scavenging invertebrates that are not killed or injured themselves could benefit from physical effects on other animals resulting from explosions in the water column or on the bottom.

High-order explosions consume most of the explosive material, leaving only small or residual amounts of explosives and combustion products. Most of the combustion products of trinitrotoluene (i.e., TNT), such as carbon dioxide and nitrogen, are common seawater constituents, although other products such as carbon monoxide are also produced (Becker, 1995). Other explosive compounds may produce different combustion products. All combustion products are rapidly diluted by ocean currents and circulation (see Section 3.2.3.1, Explosives and Explosives Byproducts). Therefore, explosives byproducts from high-order detonations would not degrade sediment or water quality or result in indirect stressors to marine invertebrates. Low-order detonations and unexploded munitions present an elevated potential for effects on marine invertebrates. Deposition of undetonated explosive materials into the marine environment can be reasonably estimated by the known failure and low-order detonation rates of high explosives (Section 3.2.3.1, Explosives and Explosives Byproducts). Explosive material not completely consumed during a detonation from munitions disposal and mine clearing training are collected after the activities are completed; therefore, potential effects are likely inconsequential and not detectable for these activities.

Exposure to relatively high concentrations of various explosive materials in sediments and in the water may result in lethal and sub-lethal effects to invertebrates. The type and magnitude of effects appear to be different among various invertebrate species and are also influenced by the type of explosive material and physical characteristics of the affected water and sediment. For example, lethal toxicity has been reported in some invertebrate species (e.g., the amphipod *Eohaustorius estuarius*) exposed to trinitrotoluene (i.e., TNT), while mortality has not been found in other species (e.g., the polychaete worm *Neanthes arenaceodentata*), even when exposed to very high concentrations (Rosen & Lotufo, 2005). Exposure to water-borne explosive materials has been found to affect reproduction or larval development in bivalve, sea urchin, and polychaete worm species (Lotufo et al., 2013). Invertebrates on the bottom may be exposed to explosive materials by ingesting contaminated sediment particles, in addition to being exposed to materials in the overlying water column or in voids in the sediment (for burrowing invertebrates). However, toxicity and other sub-lethal effects have often been associated with exposure to higher concentrations of explosive materials than the concentrations expected to occur in marine or estuarine waters of the Study Area due to training and testing activities.

Indirect effects of explosives and unexploded munitions on marine invertebrates via sediment are possible near the munitions. Rosen and Lotufo (2010) exposed mussels and deposit-feeding amphipods and polychaete worms to levels of TNT and royal demolition explosive potentially associated with a breached munition or low-order detonation. The authors found concentrations in the sediment above toxicity levels within about 1 in. of the materials, although no statistical increase in mortality was observed for any species. Concentrations causing toxicity were not found in the water column. Explosive material in the marine environment is readily degraded via several biotic and abiotic pathways, as discussed in Section 3.2.3.1 (Explosives and Explosives Byproducts). The results of studies of explosive material deposition at munitions disposal sites and active military water ranges suggest that explosives and explosives residues pose little risk to fauna living in direct contact with munitions, and that sediment is not a significant sink for these materials (Kelley et al., 2016; Koide et al., 2016; Smith & Marx, 2016). Munitions constituents and degradation products would likely be detectable only within a few feet of a degrading munition, and the spatial range of toxic sediment conditions could be less (inches). It has been suggested that the risk of toxicity to invertebrates in realistic exposure scenarios is negligible (Lotufo et al., 2013). Indirect effects of explosives and unexploded munitions on marine invertebrates via water are likely to be inconsequential. Most explosives and explosive degradation products have relatively low solubility in seawater. This means that dissolution occurs extremely slowly, and harmful concentrations of explosives and degradation products are not likely to occur in the water column. Also, the low concentration of materials delivered slowly into the water column is readily diluted by ocean currents and would be unlikely to concentrate in toxic levels. Filter feeders such as sponges or some marine worms would be exposed to chemical byproducts only in the immediate vicinity of degrading explosives (inches or less) due to the low solubility and dilution by water currents. While marine invertebrates may be adversely affected by the indirect effects of degrading explosives via water, this is unlikely in realistic scenarios.

Effects on marine invertebrates, including zooplankton, eggs, and larvae, are likely only within a very small radius of the munition (potentially inches). These effects may continue as the munition degrades over decades (Section 3.2.3.1, Explosives and Explosives Byproducts). Because most munitions are deployed as projectiles, multiple unexploded or low-order detonations would not likely accumulate on spatial scales as small as feet to inches; therefore, potential effects are likely to remain local and widely separated. Explosives, explosives byproducts, and unexploded munitions would therefore generally not be present in these habitats.

Chemicals Other Than Explosives

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, primarily propellants and combustion products, other fuels, PCBs in target vessels, other chemicals associated with munitions, and simulants (Section 3.2.3.3, Chemicals Other than Explosives). Ammonium perchlorate (a rocket and missile propellant) is the most common chemical used. Perchlorate is known to occur naturally in nitrate salts, such as those from Chile, and it may be formed by atmospheric processes such as lightning and reactions between ozone and sodium chloride in the air (associated with evaporated seawater) (Dasgupta et al., 2005; Sijimol & Mohan, 2014; U.S. Environmental Protection Agency, 2014b). Perchlorate may effect metabolic processes in plants and animals. Effects have been found in earthworms and aquatic (freshwater) insects (Smith, 2002; Srinivasan & Viraraghavan, 2009), although effects specific to marine invertebrates are unknown. Other chemicals with potential for adverse effects to invertebrates include some propellant combustion products, such as hydrogen cyanide and ammonia.

Potential effects on sediments and seawater resulting from use of chemicals are discussed in Section 3.2.3.3 (Chemicals Other than Explosives). Rockets and missiles are highly efficient at consuming propellants (for example, over 99.9 percent of perchlorate is typically consumed) and, therefore, very little residual material would enter the water column. Additionally, perchlorate does not readily absorb into sediments, potentially reducing the risk to deposit- and detritus-feeding invertebrates. Torpedoes are expended in the water and, therefore, torpedo propellant (e.g., Otto Fuel II) combustion products would enter the marine environment. Overall, analysis concludes that effects on sediments and water quality would be minimal for several reasons. The size of the area affected is large and, therefore, chemicals would not be concentrated. Most propellant combustion byproducts are benign, and those of concern (e.g., hydrogen cyanide) would be quickly diluted. Most propellants are consumed during normal operations, and the failure rate of munitions using propellants and other combustible materials is low. Most byproducts of Otto Fuel II combustion occur naturally in seawater, and most torpedoes are recovered after use, limiting the potential for unconsumed fuel to enter the water. In addition, most constituents are readily degraded by biotic and abiotic processes. Concentrations of chemicals in sediment and water are not likely to cause injury or mortality to marine invertebrates, gametes, eggs, or larvae.

Target vessels are only used during sinking exercises, which occur infrequently. Polychlorinated biphenyls may be present in certain solid materials (e.g., insulation, wires, felts, and rubber gaskets) on target vessels. The vessels are selected from a list of Navy-approved vessels that have been cleaned in accordance with USEPA guidelines. Sinking exercises must be conducted at least 50 NM offshore and in water at least 6,000 ft. deep. USEPA estimates that as much as 100 lb. of PCBs remain onboard sunken target vessels. USEPA considers the contaminant levels released during the sinking of a target to be within the standards of the Marine Protection, Research, and Sanctuaries Act (16 United States Code 1341, et seq.). Under a 2014 agreement with USEPA, the Navy will not likely use aircraft carriers or submarines as the targets for a sinking exercise. As discussed in Section 3.2.3.3 (Chemicals Other than Explosives), based on these considerations, PCBs are not evaluated further as a secondary stressor to invertebrate habitats.

Metals

Certain metals and metal-containing compounds (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) are harmful to marine invertebrates at various concentrations above background levels (Chan et al., 2012; Negri et al., 2002; Wang & Rainbow, 2008). For example, physiological effects in crabs, limpets, and mussels due to copper exposure were reported (Brown et al., 2004), although the effects were found at concentrations substantially higher than those likely to be encountered due to Navy expended materials. Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, and other military expended materials (see Section 3.2.3.2, Metals). Some effects due to metals result from the concentrating effects of bioaccumulation, which is not discussed in this section. Bioaccumulation issues are discussed in the *Ecosystem Technical Report for the Hawaii-Southern California Training and Testing (HSTT) Environmental Impact Statement* (U.S. Department of the Navy, 2013b). Secondary effects may occur when marine invertebrates are exposed by contact with the metal, contact with trace amounts in the sediment or water (e.g., from leached metals), and ingestion of contaminated sediments.

Because metals tend to precipitate out of seawater and often concentrate in sediments, potential adverse indirect effects are much more likely via sediment than water (Zhao et al., 2012). However, studies have found the concentrations of metals in the sediments of military ranges (e.g., Navy training areas such as Vieques, Puerto Rico) or munitions disposal sites, where deposition of metals is very high, to rarely be above biological effects levels (Section 3.2.3.2, Metals). For example, researchers sampled areas associated with Vieques in which live ammunition and weapons were used and found generally low concentrations of metals in the sediment (Kelley et al., 2016; Pait et al., 2010). Comparison with guidelines suggested by the National Oceanic and Atmospheric Administration's National Status and Trends Program showed that average metal concentrations were below threshold effects levels for all constituents except copper, and were below probable effects levels for all constituents. The concentration of munitions at Vieques is substantially greater than would occur in the HCTT Study Area. Evidence from a number of studies at military ranges and disposal sites indicates metal contamination is very localized (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016). Effects on invertebrates, eggs, or larvae would likely be limited to exposure in the sediment within a few inches of the object. Refer to Section 3.2.3.2 (Metals) for more detailed study results of metal contamination in sediments at military ranges.

Concentrations of metals in seawater affected by Navy training and testing activities are unlikely to be high enough to cause injury or mortality to marine invertebrates. Benthic invertebrates occurring very near (within a few inches of) Navy-derived materials on the seafloor could be affected by associated metal concentrations, but this is expected to affect relatively few individuals.

F.5 Habitats

F.5.1 Acoustic Stressors

Acoustic Stressors are not applicable to habitats, due to the lack of hearing capabilities of abiotic habitats and are not analyzed further in this section.

F.5.2 Explosive Stressors

In-water detonations are used during various mine warfare training activities, surface-to-surface gunnery exercises, air-to-surface gunnery, missile, and bombing exercises, as well as sinking exercises, in-water demolition, and other training activities. Likewise, air-to-surface gunnery, missile, and bombing tests, anti-submarine warfare tracking tests, mine warfare, detection, neutralization tests, and other testing activities also employ in-water explosives. The potential effects of in-water detonations on marine habitats are assessed according to size of charge (net explosive weight), charge radius, height above the bottom, substrate types in the area, and equations linking all these factors.

Most explosive detonations during training and testing involving the use of high-explosive munitions, including bombs, missiles, and projectile casings, would occur in the air or near the water's surface. Explosives associated with torpedoes, explosive sonobuoys, and explosive mines would occur in the water column; demolition charges could occur near the surface, in the water column, or the ocean bottom. Most surface and water column detonations would occur in waters greater than 3 NM from shore at water depths greater than 100 ft. and would not be expected to affect the bottom, although mine warfare and demolition detonations could occur in shallow water and typically in a few specific locations within the Study Area. This section only evaluates the effect of explosives placed on the bottom because the physical structure of the water column is not affected by explosions.

An explosive charge would produce percussive energy that would be absorbed and reflected by the bottom. Hard bottom would mostly reflect the energy (Berglind et al., 2009), whereas a crater would be formed in soft bottom (Gorodilov & Sukhotin, 1996). For a specific size of explosive charge, crater depths and widths would vary depending on depth of the charge and substrate type. There is a nonlinear relationship between crater size and depth of water, with relatively small crater sizes in the shallowest water, followed by a spike in size at some intermediate depth, and a decline to an average flat line (indicating similar crater size for all charge weights) at greater depth (Gorodilov & Sukhotin, 1996; O'Keeffe & Young, 1984). Radii of the craters reportedly vary little among unconsolidated substrate types (O'Keeffe & Young, 1984). On substrate types with nonadhesive particles (everything except clay), the effects should be temporary, whereas craters in clay may persist for years (O'Keeffe & Young, 1984). Soft substrate moves around with the tides and currents and depressions are only short-lived (days to weeks) unless they are maintained.

F.5.3 Energy Stressors

Energy stressors are not applicable to habitats, since activities that include the use of energy-producing devices are typically conducted at or near the surface of the water and would not affect bottom habitats. Therefore, they are not analyzed further in this section.

F.5.4 Physical Disturbance and Strike Stressors

F.5.4.1 Effects from Vessels and In-Water Devices

Vessels conducting training and testing activities in the Study Area include large ocean-going ships and submarines typically operating in waters deeper than 100 m but also occasionally transiting inshore waters from ports and through the operating areas. Training and testing activities also include smaller vessels operating in inshore waters, typically at higher speeds (greater than 10 knots). Vessels used for training and testing activities range in size from small boats (less than 40 ft.) to nuclear aircraft carriers (greater than 980 ft.) Table 3.0-14 lists representative types of vessels, including amphibious warfare vessels, used during training and testing activities. Towed mine warfare and unmanned devices are much smaller than other Navy vessels, but would also disturb the water column near the device. Some activities involve vessels towing in-water devices used in mine warfare activities. The towed devices attached to a vessel by cables are smaller than most vessels, and are not towed at high speeds. Some vessels, such as amphibious vehicles, would intentionally contact the seafloor in the surf zone.

Vessels, in-water devices, and towed in-water devices could either directly or indirectly affect any of the habitat types discussed in this section, including soft and intertidal shores, soft and hard bottoms, and artificial substrates. In addition, a vessel or device could disturb the water column enough to stir up bottom sediments, temporarily increasing the local turbidity. The shore and nearshore environment is typically very dynamic because of its constant exposure to wave action and cycles of erosion and deposition. Along high-energy shorelines like ocean beaches, these areas would be reworked by waves and tides shortly after the disturbance. Along low-energy shoreline in sheltered inshore waters, the force of vessel wakes can result in elevated erosion and resuspension of fine sediment (Zabawa & Ostrom, 1980). In deeper waters where the tide or wave action has little influence, sediments suspended into the water column would eventually settle. Sediment settlement rates are highly dependent on grain size. Disturbance of deeper bottom habitat by vessels or in-water devices is possible where the propeller wash interacts with the bottom. However, most vessel transiting in shallow, nearshore waters is confined to navigation channels where bottom disturbance only occurs with the largest vessels. An exception would be for training and testing activities that occur in shallow, nearshore environments. Turbidity caused by vessel operation in shallow water, propeller scarring, and vessel grounding could affect habitats in shallow-water areas. In addition, physical contact with hard bottom areas can cause structural damage to the substrate. However, direct effects to the substrate are typically avoided because they could slow or damage the vessel or in-water device. These disturbances would not alter the overall nature of the sediments to a degree that would impair their function as habitat. The following alternatives analysis specifies where these effects could occur in terms of number of events with vessel movement or in-water devices training/testing in different habitat areas.

F.5.4.2 Effects from Military Expended Materials

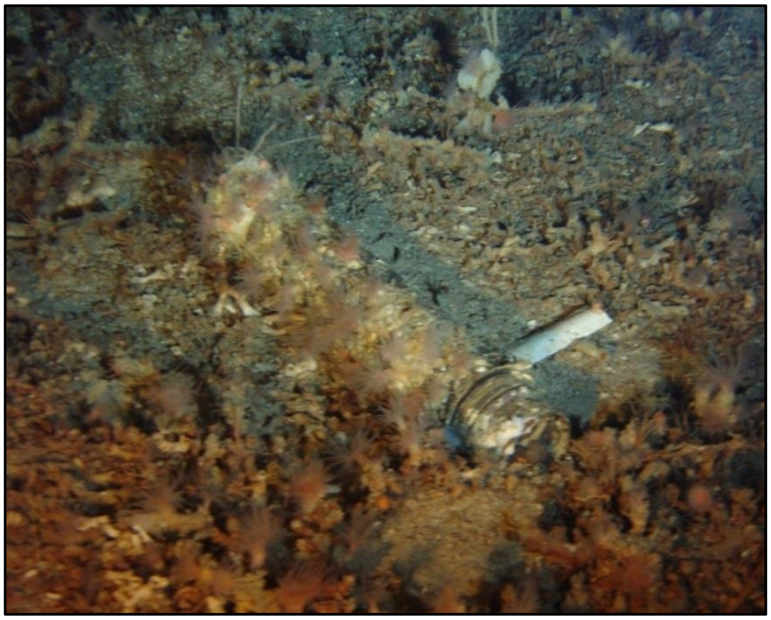
This section analyzes the potential for physical disturbance to marine substrates from the following categories of military expended materials: (1) non-explosive practice munitions, (2) fragments from high-explosive munitions, and (3) expended materials other than munitions, such as sonobuoys, expendable targets, and ship hulks. Note that expended materials do not include materials that are recovered or categorized as in-water or seafloor devices. Areas expected to have the greatest amount of expended materials are the Hawaii Study Area and California Study Area. Military expended materials have the potential to physically disturb marine substrates to the extent that they impair the substrate's ability to function as a habitat. These disturbances can result from several sources, including the effect of the expended material contacting the seafloor and moving around, the covering of the substrate by the expended material, or alteration of the substrate from one type to another.

The potential for military expended materials to physically impact marine substrates as they come into contact with the seafloor depends on several factors. These factors include, but are not limited to, the size, shape, type, density, and speed of the material through the water column; the amount of the material expended; the frequency of training or testing; water depth, water currents, or other disturbances; and the type of substrate. Most of the kinetic energy of the expended material, however, is dissipated within the first few feet of the object entering the water causing it to slow considerably by the time it reaches the substrate. Because the damage caused by a strike is proportional to the force of the strike, slower speeds result in lesser impacts. Due to the water depth at which most training and testing events take place, a direct strike on either hard bottom or artificial structures (e.g., artificial reefs and shipwrecks) is unlikely to occur with sufficient force to damage the substrate. In softer substrates (e.g., sand, mud, silt, clay, and composites), the effect of the expended material coming into contact with the seafloor, if large enough and striking with sufficient momentum, may result in a depression and a localized redistribution of sediments as they are temporarily suspended in the water column. There may also be redistribution of unconsolidated sediment in areas with sufficient flow to move the sediment, creating a pattern of scouring on one side of the material and deposition on the other.

During Navy training and testing, countermeasures such as flares and chaff are introduced into marine habitats. These types of military expended materials are not expected to affect marine habitats as strike stressors, given their smaller size and low velocity compared to projectiles, bombs, and missiles.

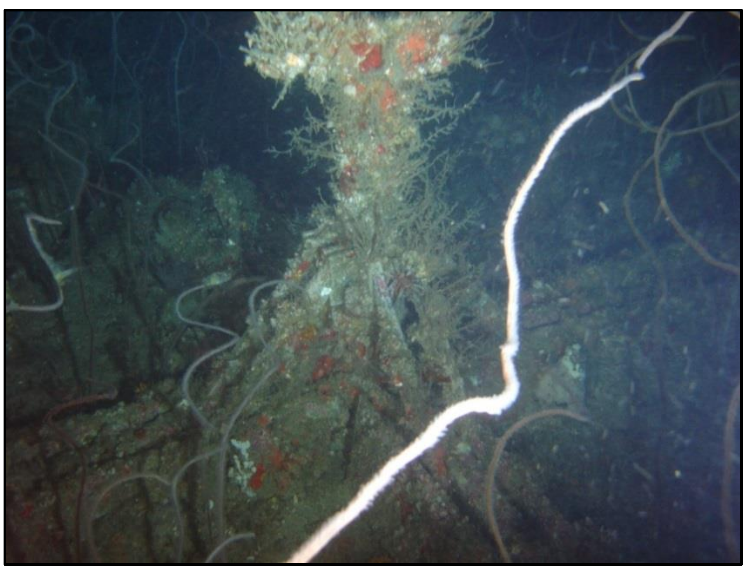
Another potential physical disturbance that military expended materials could have on marine substrates would be to cover them or to alter the type of substrate and, therefore, its function as habitat. The majority of military expended materials that settle on hard bottoms or artificial substrates, while covering the seafloor, may serve a similar habitat function as the substrate it is covering by providing a hard surface on which organisms can attach (Figure F-4 and Figure F-5). Similarity in attached organisms over the long term depends on similarity in structural features (Perkol-Finkel et al., 2006; Ross et al., 2016), fine surface texture, and mineral content (Davis, 2009). Natural hard bottom and artificial structures of a similar shape will eventually have similar communities of attached organisms if they have similar fine texture and mineral content. However, the smooth surface texture of intact military expended materials and lack of mineral content suggests a difference in species composition and associated functions. An exception would be expended materials, like the decelerators/parachutes utilized to deploy sonobuoys, lightweight torpedoes, expendable mobile anti-submarine warfare training targets, and other devices from aircraft, which would not provide a hard surface for colonization. In these cases, the hard bottom or artificial structure covered by the expended material would not be physically damaged, but would have an impaired ability to function as a habitat for colonizing or encrusting organisms. There is potential for these items to drift over shallow-water or deep-sea coral habitats.

Most military expended materials that settle on soft bottom habitats, while not damaging the actual substrate, would inhibit the substrate's ability to function as a soft-bottom habitat by covering it with a hard surface. This would effectively alter the substrate from a soft surface to a hard structure and, therefore, would alter the habitat to be more suitable for organisms more commonly found associated with hard bottom environments (U.S. Department of the Navy, 2010a, 2011). Expended materials that settle in the shallower, more dynamic environments of the continental shelf would likely be eventually covered over by sediments due to currents and other coastal processes or encrusted by organisms. Depending on the substrate properties and the hydrodynamic characteristics of the area, military expended materials may become buried rather quickly while in other areas they may persist on the surface of the seafloor for a more extended time. The offshore portion of the continental shelf experiences more sediment redistribution from oceanic currents (e.g., California Stream) than distant surface waves. The effect of oceanic currents on sediment redistribution diminishes seaward of the continental shelf break: sediment along the continental slope experiences very little reworking from surface currents and waves. In the deeper waters of the continental slope and beyond where currents do not play as large of a role, expended materials may remain exposed on the surface of the substrate with minimal change for extended periods (Figure F-6).



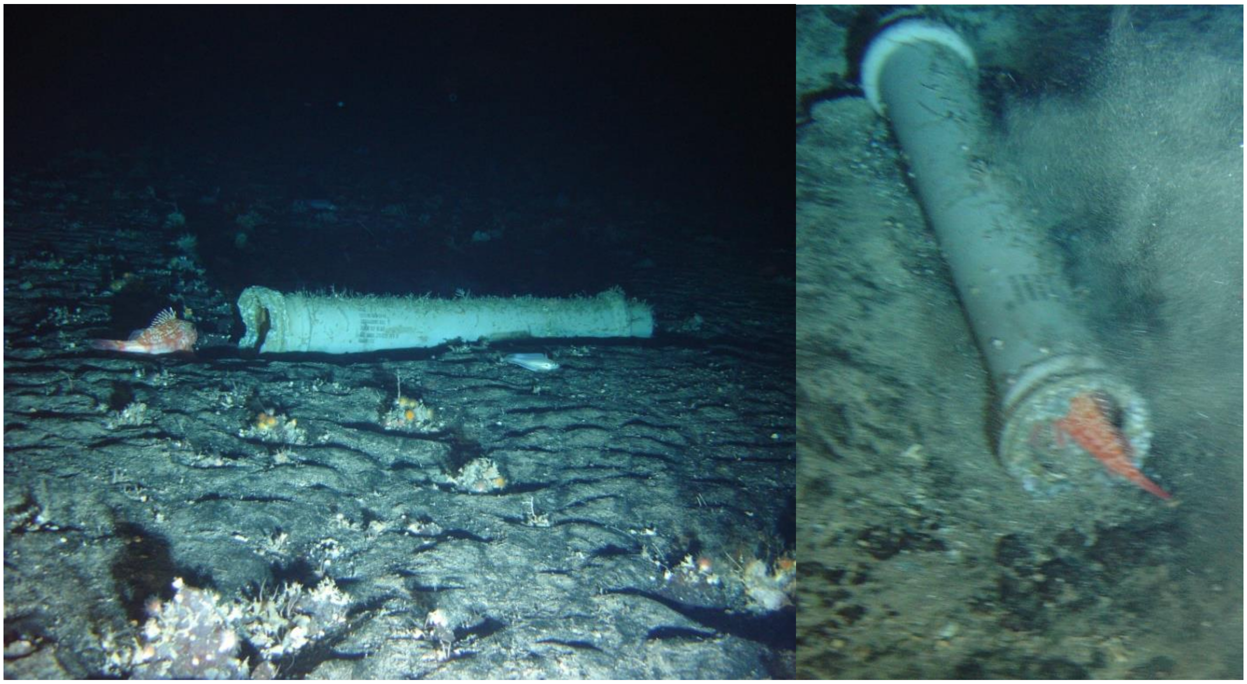
Note: Use of the smoke float as a colonizing substrate for a cluster of sea anemones (U.S. Department of the Navy, 2010a). Observed at approximately 350 meters in depth and 60 nautical miles east of Jacksonville, Florida.

Figure F-4: A Marine Marker Observed in an Area Dominated by Coral Rubble on the Continental Slope



Note: Encrusting organisms and benthic invertebrates readily colonize the artificial structure to a similar degree as the surrounding rock outcrop (U.S. Department of the Navy, 2010a). Observed on the ridge system that runs parallel to the shelf break at approximately 80 meters in depth and 55 nautical miles east of Jacksonville, Florida.

Figure F-5: An Unidentified, Non-Military Structure on Hard Bottom

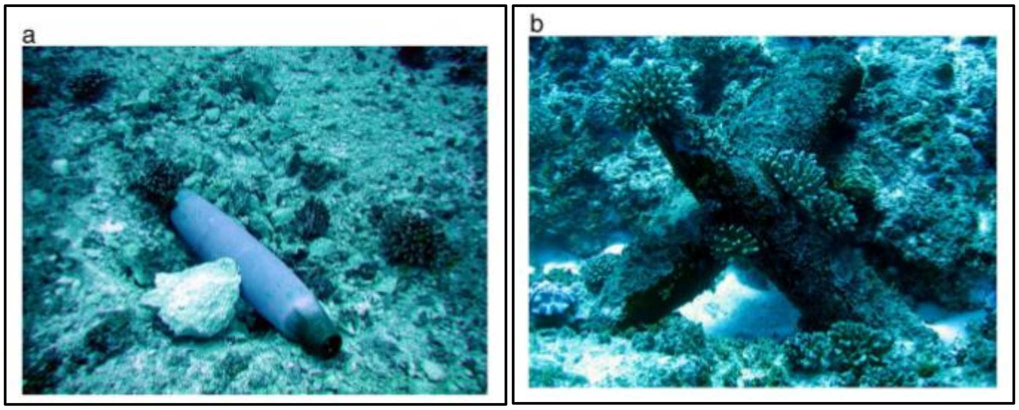


Note: The casing was observed in a sandy area on the continental slope approximately 425 meters in depth and 70 nautical miles east of Jacksonville, Florida. The casing has not become covered by sediments or encrusting organisms due to the depth and the relatively calm, current-free environment.

Figure F-6: A 76-millimeter Cartridge Casing on Soft Bottom and a Blackbelly Rosefish (*Helicolenus dactylopterus*) Using the Casing for Protection When Disturbed

Whereas the effects will accumulate somewhat through successive years of training and testing, some portion of the expended material will sink below the surface of shifting soft bottom habitat or become incorporated into natural hard bottom before crumbling into inorganic particulates. This will be the fate of military expended materials with a density greater than or equal to that of the underlying substrate (e.g., metal, cement, sand). Constituents of military expended materials that are less dense than the underlying substrate (e.g., fabric, plastic) will likely remain on the surface substrate after sinking. In this case, the effect on substrate as a habitat is likely temporary and minor due to the mobility of such materials (refer to living resources sections for more information on the entanglement and ingestion risk posed by plastic and fabric constituents of military expended materials).

The effect of dense expendable materials on bottom substrate is prolonged in the portions of the study area that are seaward of the continental shelf. Between initial settlement and burial or complete degradation, these relatively stable objects will likely function as small artificial habitats for encrusting algae, attached macroalgae/seaweed, sedentary invertebrates as well as small motile organisms (Figure F-7).



a. *MK 82 inert bomb (168 centimeters long) that directly affected the sea floor at a depth of 12 meters in Z3E on 5 or 6 September 2007; photographed on 13 September 2007. Area of destruction/ disturbance was approximately 17 square meters.*
b. *MK 82 bombs with Pocilloporid corals, algae, etc.*
Source: (Smith & Marx, 2016)

Figure F-7: Military Expended Materials Functioning as Habitat

To determine the potential level of disturbance that military expended materials have on soft, intermediate, and hard bottom substrates, an analysis to determine the impact footprint was conducted for each range complex for each alternative. Three main assumptions were made that resulted in the impact footprints calculated being considered overestimates. First, within each category of expended items (e.g., bombs, missiles, rockets, large-caliber projectiles, etc.), the size of the largest item that would be expended was used to represent the sizes of all items in the category. For example, the impact footprints of missiles used during training exercises range from 1.5 to 40 square feet. For the analyses, all missiles were assumed to be equivalent to the largest in size, or 40 square feet. Second, it was also assumed that the impact of the expended material on the seafloor was twice the size of its actual footprint. This assumption accounts for any displacement of sediments at the time of impact as well as any subsequent movement of the item on the seafloor due to currents or other forces. This should more accurately reflect the potential disturbance to soft bottom habitats, but would overestimate disturbance to hard bottom habitats since no displacement of the substrate would occur. Third, items with casings (e.g., small-, medium-, and large-caliber munitions; flares; sonobuoys; etc.) have their impact footprints doubled to account for both the item and its casing. Items and their casings were assumed to be the same size, even though, depending on the munitions, one of them is often smaller than the other.

Once the impact footprints were calculated, three analyses were performed for each range complex: (1) a conservative scenario in which potential effects to each habitat type (soft, intermediate, and hard bottom habitats) in that range complex if all expended materials settled in areas with that substrate type, (2) a proportional analysis in which potential effects to each habitat type expended materials settled proportionally across all habitat types in the area, (3) and a five-year scenario in which potential effect to the bottom habitats in that range complex over a five-year period if activities continued at anticipated levels and effects accumulated over that period. During the analyses, the same dimensions were used for high-explosive munitions as were used for non-explosive practice munitions. The total area of the seafloor covered by the expended materials should be similar regardless of whether the item is intact or fragmented, despite the fact that high-explosive munitions will explode in the air, at the surface, or in the water column and only fragments would make it to the substrate.

According to surveys conducted at Farallon De Medinilla (a U.S. Department of Defense bombing range in the Mariana Archipelago) between 1997 and 2012, there was no evidence that the condition of the living resources assessed had changed or been adversely affected to a significant degree by the training activities being conducted there. It should also be noted that the intended munition target was on the nearby land area, and water impacts were due to inaccuracy. The health, abundance, and biomass of fishes, corals, and other marine resources are comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago (Smith & Marx, 2016). However, the study noted that decline in some important reef fish during their latest surveys was likely due to increasing attention from fishermen. Also, this is expected to be an extreme case based on the proximity to shallow-water coral reefs and the increased movement of military expended materials due to the shallow margins of the islands where wave impact is more severe. Effects to habitat from military expended materials in the Study Area would be expected to be less severe. See Appendix I (Military Expended Materials and Direct Strike Impact Analyses) for detailed analyses of the effects associated with military expended materials from Navy training and testing activities.

A 2023 literature review (Naval Facilities Engineering Systems Command Pacific, 2023) undertaken to consider effects of military training and testing on reef fish contaminant bioaccumulation, human, and ecological effects in the Mariana Islands resulted in several recommendations, including:

1. A recommendation to include additional references and information in future Environmental Impact Statement documents.
2. Future fate and transport studies should utilize a broader range of environmental conditions to facilitate a better understanding of explosive dynamics within the Mariana Islands Training and Testing Study Area.
3. Use additional empirical research to reduce uncertainty in future analyses.
4. Environmental Impact Statement/Overseas Environmental Impact Statement (EIS/OEIS) sections focusing on sediments, water quality, and aquatic organisms could be strengthened with additional literature and/or estimations of the concentrations of explosive compounds generated following planned activities.
5. Recommend further studies adopting a similar approach and a wider variety of exposure scenarios, such as different explosive compositions and detonation scenarios, would be useful to minimize the uncertainty associated with applying data from munitions dumpsites to military testing and training risk assessments.

F.5.4.3 Effects from Seafloor Devices

Mine shapes or other stationary targets and anchors are typically recovered within 7–30 days following the completion of the training or testing events. As a result of their temporary nature, recovered mine shapes do not permanently affect the substrate on which they are placed, but will temporarily impair the ability of the substrate to function as a habitat for as long as the mine shape and anchor is in place. The impairment is due to the temporary covering by artificial substrate along with changes in the bathymetry around the structures due to scouring and deposition patterns around objects on a soft bottom. Mine shapes, targets, or anchors that are not recovered would potentially have effects to abiotic habitat and, depending on the type of bottom substrate, could alter the ability to function as habitat but ultimately would likely become buried (on soft bottom) or become encrusted by similar types of organisms (on hard, intermediate, or artificial surfaces).

Potential effects of precision anchoring are qualitatively different from other seafloor devices because the activity involves repeated disturbance to the same area of seafloor. Precision anchoring training exercises involve releasing of anchors in designated locations. The intent of these training exercises is to practice anchoring the vessel within 300 ft. of the planned anchorage location. These training activities typically occur within predetermined shallow water anchorage locations near ports with seafloors consisting of soft bottom substrate. The level of effect to the soft sediments would depend on the size of the anchor used, which would vary according to vessel type. As most of these activities occur in areas along navigation channels subject to strong currents and shifting sediment, disturbed areas would quickly return to pre-disturbance conditions The Navy will implement mitigation that includes not conducting precision anchoring (except in designated anchorages) within the anchor swing circle of shallow-water coral reefs, precious coral beds, live hard bottom, artificial reefs, and shipwrecks to avoid potential effects from seafloor devices on habitats in mitigation areas throughout the Study Area. Mitigation for seafloor resources was not included in the quantitative assessment of habitat effects; however, it will help the Navy further avoid the potential for effects on habitats from precision anchoring activities.

Crawlers are fully autonomous, battery-powered amphibious vehicles used for functions such as reconnaissance missions in territorial waters. These devices are used to classify and map underwater mines in shallow water areas. The crawler is capable of traveling 2 ft. per second along the seafloor and can avoid obstacles. The crawlers are equipped with various sonar sensors and communication equipment that enable these devices to locate and classify underwater objects and mines while rejecting miscellaneous clutter that would not pose a threat.

Crawlers move over the surface of the seafloor and would not harm or alter any hard substrates encountered; therefore, hard bottom habitat would not be impaired. However, fragile abiotic or biogenic structures could be harmed by the crawlers moving over the substrate (refer to living resources sections for analysis). In soft substrates, crawlers may leave a trackline of depressed sediments approximately 2 ft. wide (the width of the device) in their wake. However, since these crawlers operate in shallow water, any disturbed sediments would be redistributed by wave and tidal action shortly (days to weeks) following the disturbance. Therefore, disturbance would not impair the ability of soft sediment to function as a habitat.

F.5.5 Entanglement Stressors

Entanglement stressors are not applicable to habitats due to the lack of mobility capabilities of habitats and are not analyzed further in this section.

F.5.6 Ingestion Stressors

Ingestion stressors are not applicable to habitats due to the lack of ingestion capabilities of habitats and are not analyzed further in this section.

F.5.7 Secondary Stressors

Secondary stressors are not applicable to habitats as they are not susceptible to effects from secondary stressors and are not analyzed further in this section.

F.6 Fishes

F.6.1 Energy Stressors

F.6.1.1 Effects from In-Water Electromagnetic Devices

Several different in-water electromagnetic devices are used during training and testing activities. A discussion of the characteristics of energy introduced into the water through naval training and testing activities and the relative magnitude and location of these activities is presented in Section 3.0.3.3.3.1 (In-Water Electromagnetic Devices), while Table B-1 (Appendix B, Activity Stressor Matrices) lists the activities in each alternative that use the devices.

A comprehensive review of information regarding the sensitivity of marine organisms to electric and magnetic impulses is presented in Bureau of Ocean Energy Management (2011). The synthesis of available data and information contained in this report suggests that while many fish species (particularly elasmobranchs) are sensitive to electromagnetic fields (Hore, 2012), further investigation is necessary to understand the physiological response and magnitude of the potential effects. Most examinations of electromagnetic fields on marine fishes have focused on buried undersea cables associated with offshore wind farms in European waters (Boehlert & Gill, 2010; Gill, 2005; Ohman et al., 2007).

Many fish groups, including lampreys, elasmobranchs, eels, salmonids, and stargazers, have an acute sensitivity to electrical fields, known as electroreception (Bullock et al., 1983; Helfman et al., 2009). Fishes likely use the same sensory organs (e.g., lateral line system particularly around the head) for electroreception and also for detecting sounds. Some species of sharks, such as the scalloped hammerhead, have small pores near the nostrils, around the head, and on the underside of the snout, or rostrum called ampullae of Lorenzini to detect the electromagnetic signature of their prey. Electroreceptors are thought to aid in navigation, orientation, and migration of sharks and rays (Kalmijn, 2000). In elasmobranchs, behavioral and physiological response to electromagnetic stimulus varies by species and age, and appears to be related to foraging behavior (Rigg et al., 2009). Many elasmobranchs respond physiologically to electric fields of 10 nanovolts per centimeter (cm) and behaviorally at 5 nanovolts per cm (Collin & Whitehead, 2004), while Kajiura & Holland (2002) showed juvenile scalloped hammerhead sharks detected and behaviorally responded to electric fields of less than 1 nanovolt per cm.

There are two general types of electroreceptor organs in fishes (Helfman et al., 2009). Ampullary receptors, located in recesses in the skin, are connected to the surface by a canal filled with a conductive gel and are sensitive to electric fields of low frequency (<0.1–25 Hz). Tuberous receptors are located in depressions of the epidermis, are covered with loosely packed epithelial cells, and detect higher frequency electric fields (50 Hz to > 2 kHz). They are typically found in fishes that use electric organs to produce their own electric fields. The distribution of electroreceptors on the head of these fishes, especially around the mouth, suggests that these sensory organs may be used in foraging. Additionally, some researchers hypothesize that the electroreceptors aid in social communication (Collin & Whitehead, 2004).

While elasmobranchs and other fishes can sense the level of the earth's electromagnetic field, the potential effects on fishes resulting from changes in the strength or orientation of the background field are not well understood. When the electromagnetic field is enhanced or altered, sensitive fishes may experience an interruption or disturbance in normal sensory perception. Research on the electrosensitivity of sharks indicates that some species respond to electrical impulses with an apparent avoidance reaction (Helfman et al., 2009; Kalmijn, 2000). This avoidance response has been exploited as a shark deterrent, to repel sharks from areas of overlap with human activity (Marcotte & Lowe, 2008). A recent study on cat sharks (*Scyliorhinus canicula*) demonstrated that sharks may show habituation to electrical fields over short-term exposures (Kimber et al., 2014). Other studies suggest that sharks are attracted to electromagnetic sources when conditions in the water hinder their other senses, such as sight and hearing. This attraction to electromagnetic sources helps sharks to find prey when in these low sensory conditions (Fields, 2007).

The mechanism for direct sensing of magnetic fields is unknown; however, the presence of magnetite (a magnetic mineral) in the tissues of some fishes such as tunas and salmon, or other sensory systems such as the inner ear and the lateral line system, may be responsible for electromagnetic reception (Helfman et al., 2009). Magnetite of biogenic origins has been documented in the lateral line of the European eel (*Anguilla anguilla*) (Moore & Riley, 2009). Some species of salmon, tuna, and stargazers have likewise been shown to respond to magnetic fields and may also contain magnetite in their tissues (Helfman et al., 2009).

Experiments with electromagnetic pulses can provide indirect evidence of the range of sensitivity of fishes to similar stimuli. Two studies reported that exposure to electromagnetic pulses do not have any effect on fishes (Hartwell et al., 1991; Nemeth & Hocutt, 1990). The observed 48-hour mortality of small estuarine fishes (e.g., sheepshead minnow, mummichog, Atlantic menhaden, striped bass, Atlantic silverside, fourspine stickleback, and rainwater killifish) exposed to electromagnetic pulses of 100–200 kilovolts per m (10 nanoseconds per pulse) from distances greater than 50 m was not statistically different than the control group (Hartwell et al., 1991; Nemeth & Hocutt, 1990). During a study of Atlantic menhaden, there were no statistical differences in swimming speed and direction (toward or away from the electromagnetic pulse source) between a group of individuals exposed to electromagnetic pulses and the control group (Hartwell et al., 1991; Nemeth & Hocutt, 1990).

Electromagnetic sensitivity in some marine fishes (e.g., salmonids) is already well developed at early life stages (Ohman et al., 2007); however, most of the limited research that has occurred focuses on adults. A laboratory study on Atlantic salmon showed no behavioral changes for adults and post-smolts passing through an area with a 50 Hz magnetic field activated (Armstrong et al., 2015). Some species appear to be attracted to undersea cables, while others show avoidance (Ohman et al., 2007). Under controlled laboratory conditions, the scalloped hammerhead (*Sphyrna lewini*) and sandbar shark (*Carcharhinus plumbeus*) exhibited altered swimming and feeding behaviors in response to very weak electric fields (less than 1 nanovolt per cm) (Kajiura & Holland, 2002). In a test of sensitivity to fixed magnets, five Pacific sharks were shown to react to magnetic field strengths of 2,500–234,000 microtesla at distances ranging between 0.26 and 0.58 m and avoid the area (Rigg et al., 2009). A field trial in the Florida Keys demonstrated that southern stingrays (*Dasyatis americana*) and nurse sharks (*Ginglymostoma cirratum*) detected and avoided a fixed magnetic field producing a flux of 95,000 microtesla (O'Connell et al., 2010). A field study on white sharks (*Carcharodon carcharias*) in South Africa suggested behavioral changes in the sharks when approaching a towed prey item with an active electromagnetic field (Huveneers et al., 2013). No change was noticed in the sharks' behavior towards a static prey item. The maximum electromagnetic fields typically generated during Navy training and testing activities is approximately 2,300 microtesla.

Potential effects of electromagnetic activity on adult fishes may not be relevant to early life stages (eggs, larvae, juveniles) due to ontogenic (life stage-based) shifts in habitat utilization (Botsford et al., 2009; Sabates et al., 2007). Some skates and rays produce egg cases that occur on the bottom, while many neonate and adult sharks occur in the water column or near the water surface. Exposure of eggs and larvae (ichthyoplankton) to electromagnetic fields would be low since their distributions are extremely patchy. Early life history stages of ESA-listed steelhead occur in freshwater or estuarine habitats outside of the Study Area. For many sharks, skates, rays, and livebearers, the fecundity and natural mortality rates are much lower, and the exposure of the larger neonates and juveniles to electromagnetic energy would be similar across life stages for these species.

Based on current literature, only the fish groups identified above are capable of detecting electromagnetic fields (primarily elasmobranchs, salmonids, tuna, eels, and stargazers) and thus will be carried forward in this section. The remaining major fish groups will not be presented further. Aspects of electromagnetic stressors that are applicable to marine organisms in general are described in Section 1.2 (Conceptual Framework for Assessing Effects from Energy-Producing Activities) of this appendix.

F.6.2 Physical Disturbance and Strike Stressors

How a physical strike affects a fish depends on the relative size of the object potentially striking the fish and the location of the fish in the water column. Before being struck by an object, salmon for example, would sense a pressure wave through the water (Hawkins & Johnstone, 1978) and have the ability to swim away from the oncoming object. The movement generated by a large object moving through the water would simply displace small fishes in open water, such as anchovies and sardines. Some fish might have time to detect the approaching object and swim away; others could be struck before they become aware of the object. An open-ocean fish that is displaced a small distance by movements from an object falling into the water nearby would likely continue on its original path as if nothing had happened. However, a bottom-dwelling fish near a sinking object would likely be disturbed, and may exhibit a general stress response, as described in Section 1 (Biological Resource Methods) of this appendix. As in all vertebrates, the function of the stress response in fishes is to rapidly alter blood chemistry levels or ratios to prepare the fish to flee or fight (Helfman et al., 2009). This generally adaptive physiological response can become a liability to the fish if the stressor persists and the fish is not able to return to its baseline physiological state. When stressors are chronic, the fish may experience reduced growth, health, or survival (Wedemeyer et al., 1990). If the object hits the fish, direct injury (in addition to stress) or death may result.

The potential responses to a physical strike are varied, but include behavioral changes such as avoidance, altered swimming speed and direction, physiological stress, and physical injury or mortality. Despite their ability to detect approaching vessels using a combination of sensory cues (e.g., sight, hearing, and lateral line), larger slow-moving fishes (e.g., whale sharks [*Rhincodon typus*], basking sharks [*Cetorhinus maximus*], manta rays [*Manta* spp.), and ocean sunfish) cannot avoid all collisions, with some collisions resulting in mortality (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Foderaro, 2015; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016; Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007). Many fishes respond by darting quickly away from the stimulus. Some other species may respond by freezing in place and adopting cryptic coloration, while still some other species may respond in an unpredictable manner. Regardless of the response, the individual must stop its current activity and divert its physiological and cognitive attention to responding to the stressor (Helfman et al., 2009). The energy costs of reacting to a stressor depend on the specific situation, but in all cases the caloric requirements of stress reactions reduce the amount of energy available to the fish for other functions, such as predator avoidance, reproduction, growth, and maintenance (Wedemeyer et al., 1990).

The ability of a fish to return to its previous activity following a physical strike (or near-miss resulting in a stress response) is a function of a variety of factors. Some fish species are more tolerant of stressors than others and become re-acclimated more easily. Within a species, the rate at which an individual recovers from a physical strike may be influenced by its age, sex, reproductive state, and general condition. A fish that has reacted to a sudden disturbance by swimming at burst speed would tire after only a few minutes; its blood hormone and sugar levels (cortisol and glucose) may not return to normal for up to, or longer than, 24 hours. During its recovery period, the fish would not be able to attain burst speeds and would be more vulnerable to predators (Wardle, 1986). If the individual were not able to regain a steady state following exposure to a physical stressor, it may suffer reduced immune function and even death (Wedemeyer et al., 1990).

Potential effects of physical disturbance or strike to adults may be different than for other life stages (e.g., eggs, larvae, juveniles) because these life stages do not necessarily occur together in the same location (Botsford et al., 2009; Sabates et al., 2007), and because they have different response capabilities. The numbers of eggs and larvae exposed to vessel movements would be low relative to total ichthyoplankton biomass (Able & Fahay, 1998); therefore, measurable effects on fish recruitment would not be expected. Also, the early life stages of most marine fishes (excluding sharks and other livebearers) already have extremely high natural mortality rates (10–85 percent per day) from predation on these life stages (Helfman et al., 2009), and therefore, most eggs and larvae are not expected to survive to the next life stage (Horst, 1977).

F.6.2.1 Effects from Vessels and In-Water Devices

Representative Navy vessel types, lengths, and speeds of vessels used in the Study Area is presented in Table 3.0-14. The number and location of activities for each Alternative is presented in Table 3.0-17, while Table B-1 in Appendix B (Activity Stressor Matrices) lists the activities in each alternative that use the devices.

Vessels do not normally collide with adult fishes, most of which can detect and avoid them. One study on Barents Sea capelin (*Mallotus villosus*) behavioral responses to vessels showed that most adults exhibit avoidance responses to engine noise, sonar, depth finders, and fish finders (Jorgensen et al., 2004), reducing the potential for vessel strikes. Misund (1997) found that fishes, such as polar cod (*Boreogadus saida*), haddock (*Melanogrammus aeglefinus*), jack mackerel (*Trachurus symmetricus*), sardine (*Sardina pilchardus*), herring, anchovy (*Engraulis ringens*), and capelin, that were ahead of a ship showed avoidance reactions and did so at ranges of 50–350 m. When the vessel passed over them, some fishes responded with sudden avoidance responses that included lateral avoidance or downward compression of the school. Conversely, Rostad, (2006) observed that some fishes are attracted to different types of vessels (e.g., research vessels, commercial vessels) of varying sizes, noise levels, and habitat locations. Fishes involved in that study included herring (*Clupea harengus*), sprat (*Sprattus sprattus*), and whitefish (*Merlangius merlangu*s) (Rostad et al., 2006). Fish behavior in the vicinity of a vessel is therefore quite variable, depending on the type of fish, its life history stage, behavior, time of day, and the sound propagation characteristics of the water (Schwartz, 1985). Early life stages of most fishes could be displaced by vessels and not struck in the same manner as adults of larger species. However, a vessel's propeller movement or propeller wash could entrain early life stages. The low-frequency sounds of large vessels or accelerating small vessels caused avoidance responses among herring (Chapman & Hawkins, 1973), but avoidance ended within 10 seconds after the vessel departed.

There are a few notable exceptions to this assessment of potential vessel strike effects on fish groups. Large slow-moving fishes such as whale sharks (Ramirez-Macias et al., 2012; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007), basking sharks (Pacific Shark Research Center, 2017; The Shark Trust, 2017), and manta rays (Braun et al., 2015; Couturier et al., 2012; Deakos et al., 2011; Germanov & Marshall, 2014; Graham et al., 2012; Miller & Klimovich, 2016) may occur near the surface in open-ocean and coastal areas, thus making them more susceptible to ship strikes which may result in blunt trauma, lacerations, fin damage, or mortality. Stevens (2007) noted that increases in the numbers and sizes of shipping vessels in the modern cargo fleets make it difficult to gather strike-related mortality data for whale sharks because personnel on large ships are often unaware of collisions; therefore, the occurrence of vessel strikes is likely much higher than has been documented by the few studies that have been conducted. This holds true not just for whale sharks, but also for any of the aforementioned fish species.

Based on the typical physiological responses described in Section 3.5.3.4 (Physical Disturbance and Strike Stressors), vessel movements are not expected to compromise the general health or condition of individual fishes, except for large slow-moving fishes such as whale sharks, basking sharks, manta rays, and ocean sunfish (Foderaro, 2015; Rowat et al., 2007; Speed et al., 2008; Stevens, 2007).

In-water devices do not normally collide with adult fishes, as most can detect and avoid them. Fish responses to in-water devices would be similar to those discussed above for vessels. Fishes would likely show varying behavioral avoidance responses to in-water devices. Early life stages of most fishes could be displaced by in-water devices and not struck in the same manner as adults of larger species. Because in-water devices are continuously moving, most fishes are expected to move away from them or to follow behind them.

F.6.2.2 Effects from Military Expended Materials

While disturbance or strike from any of these objects as they sink through the water column is possible, it is not very likely for most expended materials because the objects generally sink through the water slowly and can be avoided by most, if not all fishes. Therefore, with the exception of sinking exercises, the discussion of military expended materials strikes focuses on strikes at the surface or in the upper water column from fragments (of high-explosives) and projectiles because those items have a greater potential for a fish strike as they hit the water, before slowing down as they move through the water column.

F.6.2.2.1 Ship Hulk

During a sinking exercise, aircraft, ship, and submarine crews fire or drop munitions on a seaborne target, usually a clean deactivated ship (Section 3.2, Sediments and Water Quality), which is deliberately sunk using multiple weapon systems. A description of sinking exercises is presented in Appendix A (Navy Activity Descriptions). Sinking exercises occur in specific open ocean areas, outside of the coastal range complexes, in waters exceeding 3,000 m (9,842.5 ft.) in depth. Direct munitions strikes from the various weapons used in these exercises are a source of potential effect. However, these effects are discussed for each of those weapons categories in this section and are not repeated in the respective sections. Therefore, the analysis of sinking exercises as a strike potential for benthic fishes is discussed in terms of the ship hulk landing on the seafloor.

F.6.2.2.2 Small-. Medium-, and Large-Caliber Projectiles

Various types of projectiles could cause a temporary (seconds), localized effect when they strike the surface of the water. Current Navy training and testing in the Study Area, such as gunnery exercises and testing events, include firing a variety of weapons and using a variety of non-explosive training and testing rounds, including 5-inch naval gun shells, and small-, medium-, and large-caliber projectiles. The larger-caliber projectiles are primarily used in the open ocean beyond 20 NM. Direct munitions strikes from firing weapons are potential stressors to fishes. There is a remote possibility that an individual fish at or near the surface may be struck directly if it is at the point of impact at the time of non-explosive munitions delivery. Expended rounds may strike the water surface with sufficient force to cause injury or mortality. However, limited fish species swim right at, or near, the surface of the water (e.g., with the exception of pelagic sharks, herring, salmonids, flyingfishes, jacks, tuna, mackerels, billfishes, ocean sunfishes, and other similar species).

Various projectiles would fall on soft or hard bottom habitats, where they could either become buried immediately in the sediments, or sit on the bottom for an extended time period. Most munitions would sink through the water column and come to rest on the seafloor, stirring up sediment and possibly inducing an alarm response, displacing, or injuring nearby fishes in extremely rare cases. Particular effects on a given fish species would depend on the size and speed of the munitions, the water depth, the number of rounds delivered, the frequency of training and testing, and the sensitivity of the fish (U.S. Department of the Navy, 2013c).

F.6.2.2.3 Bombs, Missiles, and Rockets

Direct munitions strikes from bombs, missiles, and rockets are potential stressors to fishes. Some individual fish at or near the surface may be struck directly if they are at the point of impact at the time of non-explosive munitions delivery. However, most missiles hit their target or are disabled before hitting the water. Thus, most of these missiles hit the water as fragments, which quickly dissipates their kinetic energy within a short distance of the surface. A limited number of fishes swim right at, or near, the surface of the water, as described for small-, medium-, and large-caliber projectiles.

Even though statistical modeling conducted for the Study Area (discussed in Appendix I, Military Expended Materials and Direct Strike Impact Analyses) indicates that the probability of military expended materials striking marine mammals or sea turtles is extremely low, modeling could not be conducted to estimate the probability of military expended material strikes on an individual fish. This is primarily due to the lack of fish density data available at the scale of a range complex or testing range.

In lieu of strike probability modeling, the number, size, and area of potential impact (or "footprints") of each type of military expended material is presented in Appendix I (Military Expended Materials and Direct Strike Impact Analyses). The application of this type of footprint analysis to fish follows the notion that a fish occupying the impact area could be susceptible to potential effects, either at the water surface (e.g., pelagic sharks, salmonids, flyingfishes, jacks, tunas, mackerels, billfishes, and ocean sunfishes) or as military expended material falls through the water column and settles to the bottom (e.g., flounders, skates, and other benthic fishes listed in Table 3.6-2). Furthermore, most of the projectiles fired during training and testing activities are fired at targets, and most projectiles hit those targets, so only a very small portion of those would hit the water with their maximum velocity and force. Of that small portion, a small number of fish at or near the surface (pelagic fishes) or near the bottom (benthic fishes) may be directly affected if they are in the target area and near the expended item that hits the water surface (or bottom).

Propelled fragments are produced by an exploding bomb. Close to the explosion, fishes could potentially sustain injury or death from propelled fragments (Stuhmiller et al., 1991). However, studies of underwater bomb blasts have shown that fragments are large and decelerate rapidly (O'Keeffe & Young, 1984; Swisdak & Montanaro, 1992), posing little risk to marine organisms.

Fish disturbance or strike could result from bomb fragments (after explosion) falling through the water column in very small areas compared to the vast expanse of the testing ranges, range complexes, or the remainder of the Study Area. The expected reaction of fishes exposed to military expended materials would be to immediately leave the area where bombing is occurring, thereby reducing the probability of a fish strike after the initial expended materials hit the water surface. When a disturbance of this type concludes, the area would be repopulated and the fish stock would rebound, with inconsequential effects on the resource (Lundquist et al., 2010).

F.6.2.3 Effects from Seafloor Devices

The number and location of activities including seafloor devices is presented in Section 3.0.3.3.4.3 (Seafloor Devices). Additional information on stressors by testing and training activity is provided in Appendix B (Activity Stressor Matrices). Seafloor devices include items that are placed on, dropped on, or moved along the seafloor such as mine shapes, anchor blocks, anchors, bottom-placed instruments, bottom-crawling unmanned underwater vehicles, and bottom-placed targets that are not expended. As discussed in the military expended materials strike section, objects falling through the water column would slow in velocity as they sink toward the bottom and could be avoided by most, if not all fish.

Aircraft deployed mine shapes, anchor blocks, anchors, and bottom-placed instruments, and targets all have the potential to strike fish upon deployment as they sink through the water column and settle on the seafloor. Unmanned underwater vehicles (e.g., bottom crawl vehicles) also have the potential to strike a fish. Some fishes are attracted to virtually any tethered object in the water column for food or refuge (Dempster & Taquet, 2004) and could be attracted to a non-explosive mine assembly. However, while a fish might be attracted to the object, its sensory abilities allow it to avoid colliding with fixed tethered objects in the water column (Bleckmann & Zelick, 2009), so the likelihood of a fish striking one of these objects is implausible. Therefore, strike hazards associated with collision into other seafloor devices such as deployed mine shapes or anchored devices are highly unlikely to pose any strike hazard to fishes and are not discussed further.

F.6.3 Entanglement Stressors

This section evaluates potential entanglement effects of various types of expended materials used by the Navy during training and testing activities within the Study Area. The likelihood of fishes being affected by an entanglement stressor is a function of the physical properties, location, and buoyancy of the object and the behavior and physical features of the fish, as described in Section 1.4 (Conceptual Framework for Assessing Effects from Entanglement) of this appendix. Two types of military expended materials are considered here: (1) wires and cables and (2) decelerators/parachutes.

Most entanglement observations involve abandoned or discarded nets, lines, and other materials that form loops or incorporate rings (Derraik, 2002; Keller et al., 2010; Laist, 1987; Macfadyen et al., 2009). A 25-year dataset assembled by the Ocean Conservancy reported that fishing line, rope, and fishing nets accounted for approximately 68 percent of fish entanglements, with the remainder due to encounters with various items such as bottles, cans, and plastic bags (Ocean Conservancy, 2010). No occurrences involving military expended materials were documented.

Fish entanglement occurs most frequently at or just below the surface or in the water column where objects are suspended. A smaller number involve objects on the seafloor, particularly abandoned fishing gear designed to catch bottom fishes or invertebrates (Ocean Conservancy, 2010). More fish species are entangled in coastal waters and the continental shelf than elsewhere in the marine environment because of higher concentrations of human activity (e.g., fishing, sources of entangling debris), higher fish abundances, and greater species diversity (Helfman et al., 2009; Macfadyen et al., 2009). The consequences of entanglement range from temporary and inconsequential to major physiological stress or mortality.

Some fishes are more susceptible to entanglement in derelict fishing gear and other marine debris, compared to other fish groups. Physical features, such as rigid or protruding snouts of some elasmobranchs (e.g., the wide heads of hammerhead sharks), increase the risk of entanglement compared to fishes with smoother, more streamlined bodies (e.g., lamprey and eels). Most fishes, except for jawless fishes and eels that are too smooth and slippery to become entangled, are susceptible to entanglement gear specifically designed for that purpose (e.g., gillnets).

The overall effects of entanglement are highly variable, ranging from temporary disorientation to mortality due to predation or physical injury. The evaluation of a species' entanglement potential should consider the size, location, and buoyancy of an object as well as the size, physical characteristics, and behavior of the fish species.

The following sections seek to identify entanglement potential due to military expended material. Where appropriate, specific geographic areas (open ocean areas, range complexes, and bays and inland waters) of potential effect are identified.

F.6.3.1 Effects from Wires and Cables

Fiber optic cables, guidance wires, and sonobuoys (which contain a wire) are used during training and testing activities. The number and location of items expended under each alternative is presented in Section 3.0.3.3.5.1 (Wires, Cables, and Nets), with additional details provided in Appendix B (Activity Stressor Matrices).

Fish groups identified in Table 3.6-2 that could be susceptible to entanglement in expended cables and wires are those such as sawfishes, with elongated snouts lined with tooth-like structures that easily snag on other similar marine debris, such as derelict fishing gear (Macfadyen et al., 2009). Some elasmobranchs (including hammerhead sharks and manta rays) and billfishes occurring within the offshore and continental shelf portions of the range complexes and testing ranges (where the potential for entanglement would occur) could be susceptible to entanglement in cables and wires. Species occurring outside the specified areas within these range complexes would not be exposed to fiber optic cables, guidance wires, or sonobuoy wire.

Once a guidance wire is released, it is likely to sink immediately and remain on the seafloor. In some cases, the wire may snag on a hard structure near the bottom and remain partially or completely suspended. The types of fish that encounter any given wire would depend, in part, on its geographic location and vertical location in the water column. In any situation, the most likely mechanism for entanglement would involve fish swimming through loops in the wire that tighten around it; however, loops are unlikely to form in a guidance wire or sonobuoy wire because of its size and rigidity (Environmental Sciences Group, 2005b).

Because of their physical characteristics, guidance wires and fiber optic cables pose a potential, though unlikely, entanglement risk to susceptible fishes. Analysis of potential entanglement for fishes is based on abandoned monofilament, nylon, and polypropylene lines used in commercial nets. Such derelict fishing gear is abundant in the ocean (Macfadyen et al., 2009) and pose a greater hazard to fishes than wires expended by the Navy. Fishing gear materials often have breaking strengths that can be up to orders of magnitude greater than that of guidance wire and fiber optic cables (Environmental Sciences Group, 2005b), and are far more prone to tangling, as discussed in Section 3.0.3.3.5.1 (Wires, Cables, and Nets). Fiber optic cables do not easily form loops, are brittle, and break easily if bent, so they pose a negligible entanglement risk. Additionally, the encounter rate and probability of effect from guidance wires and fiber optic cables are low, as few are expended (see Chapter 2, Description of Proposed Action and Alternatives, for further information).

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin gauge dual conductor and hard draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the wire is a maximum of 40 lb. (Swope & McDonald, 2013). The length of the cable is housed in a plastic canister dispenser, which remains attached upon deployment. The length of wire that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The cable runs through the stabilizing system and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy but pose no entanglement risk. Each sonobuoy has a saltwater-activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor.

The sonobuoy itself is not considered an entanglement hazard for upon deployment (Environmental Sciences Group, 2005b), but its components may pose an entanglement hazard once released into the ocean. Aerial-launched sonobuoys are deployed with a decelerator/parachute. Sonobuoys contain cords, electronic components, and plastic mesh that may entangle fish (Environmental Sciences Group, 2005b). Open-ocean filter feeding species, such as basking sharks, whale sharks, scalloped hammerhead sharks, oceanic whitetip sharks, and manta rays could become entangled in these items, whereas smaller species could become entangled in the plastic mesh in the same manner as a small gillnet. Since most sonobuoys are expended in offshore areas, many coastal fishes would not encounter or have any opportunity to become entangled in materials associated with sonobuoys.

F.6.3.2 Effects from Decelerators/Parachutes

Decelerators/Parachutes of varying sizes are used during training and testing activities. Section 3.0.3.3.5.2 (Decelerators/Parachutes) describes the use and platforms where decelerators/parachutes would be released into the marine environment. Table 3.0-25 presents the size categories for decelerators/parachutes expended during training and testing activities that could present an entanglement risk to fishes. The types of activities that use decelerators/parachutes, physical characteristics and size of decelerators/parachutes, locations where decelerators/parachutes are used, and the number of decelerator/parachute activities proposed under each alternative are presented in Appendix B (Activity Stressor Matrices). Fishes face many potential entanglement scenarios in abandoned monofilament, nylon, polypropylene line, and other derelict fishing gear in the nearshore and offshore marine habitats of the Study Area (Macfadyen et al., 2009; Ocean Conservancy, 2010). Abandoned fishing gear is dangerous to fishes because it is abundant, essentially invisible, strong, and easily tangled. In contrast, decelerators/parachutes are rare, highly visible, and not designed to capture fishes. The weak entangling features reduce the risk to ESA-protected fishes.

Once a decelerator/parachute has been released to the water, it poses a potential entanglement risk to fishes. The Naval Ocean Systems Center identified the potential effects of torpedo air launch accessories, including decelerators/parachutes, on fish (U.S. Department of the Navy, 2001c). Unlike other materials in which fish become entangled (such as gill nets and nylon fishing line), the decelerator/parachute is relatively large and visible, reducing the chance that visually oriented fish would accidentally become entangled in it. No cases of fish entanglement have been reported for decelerators/parachutes (Ocean Conservancy, 2010; U.S. Department of the Navy, 2001a). Entanglement in a newly expended decelerator/parachute and its attachment lines while it is in the water column is unlikely because fish generally react to sound and motion at the surface with a behavioral reaction by swimming away from the source (see Section 3.6.3.5.2, Decelerators/Parachutes) and would detect the oncoming decelerator/parachute in time to avoid contact. While the decelerator/parachute is sinking, fish would have ample opportunity to swim away from the large moving object. Even if the decelerator/parachute landed directly on a fish, it would likely be able to swim away faster than the decelerator/parachute would sink because the resistance of the water would slow the decelerator/parachute's downward motion.

Once the decelerator/parachute is on the bottom, however, it is feasible that a fish could become entangled in the decelerator/parachute or its attachment lines while diving and feeding, especially in deeper waters where it is dark. If the decelerator/parachute is dropped in an area of strong bottom currents, it could billow open and pose a short-term entanglement threat to large fish feeding on the bottom. Benthic fishes with elongated spines could become caught on the decelerator/parachute or lines. Most sharks and other smooth-bodied fishes are not expected to become entangled because their soft, streamlined bodies can more easily slip through potential snares. A fish with spines or protrusions (e.g., some sharks [including hammerheads], manta rays, and billfishes,) on its body that swam into the decelerator/parachute or a loop in the lines, and then struggled, could become bound tightly enough to prevent escape. Although this scenario is possible based on the structure of the materials and the shape and behavior of fishes, it is not considered a likely event.

F.6.4 Ingestion Stressors

Aspects of ingestion stressors that are applicable to marine organisms in general are presented in Section 1.5 (Conceptual Framework for Assessing Effects from Ingestion) of this appendix. Ingestion of expended materials by fishes could occur in coastal and open ocean areas, and can occur at or just below the surface, in the water column, or at the seafloor depending on the size and buoyancy of the expended object and the feeding behavior of the fish. Floating material is more likely to be eaten by fishes that feed at or near the water surface (e.g., ocean sunfish, basking sharks, manta rays, or flyingfishes), while materials that sink to the seafloor present a higher risk to bottom-feeding fishes (e.g., rockfishes, hammerhead sharks, skates, and flatfishes).

It is reasonable to assume that any item of a size that can be swallowed by a fish could be eaten at some time; this analysis focuses on ingestion of materials in two locations: (1) at the surface or water column and (2) at the seafloor. The potential for fish, including the ESA-listed fish species, to encounter and ingest expended materials is evaluated with respect to their feeding group and geographic range, which influence the probability that they would eat military expended materials.

The Navy expends the following types of materials during training and testing in the Study Area that could become ingestion stressors: non-explosive practice munitions (small- and medium-caliber), fragments from high-explosives, fragments from targets, chaff, flare casings (including plastic end caps and pistons), and small decelerators/parachutes. The location and number of activities that expend these items are detailed in Section 3.0.3.3.6 (Ingestion Stressors) and in Appendix B (Activity Stressor Matrices). Metal items eaten by fish are generally small (such as fishhooks, bottle caps, and metal springs), suggesting that small- and medium-caliber projectiles, pistons, or end caps (from chaff canisters or flares) are more likely to be ingested. Both physical and toxicological effects could occur as a result of consuming metal or plastic materials (Dantas et al., 2012; Davison & Asch, 2011; Possatto et al., 2011). Ingestion of plastics has been shown to increase hazardous chemicals in fish leading to liver toxicity of fishes (Rochman et al., 2013). Items of concern are those of ingestible size that either drift at or just below the surface (or in the water column) for a time or sink immediately to the seafloor. The likelihood that expended items would cause a potential effect on a given fish species depends on the size and feeding habits of the fish and the rate at which the fish encounters the item and the composition of the item. In this analysis only small- and medium-caliber munitions (or small fragments from larger munitions), chaff, small decelerators/parachutes, and end caps and pistons from flares and chaff cartridges are considered to be of ingestible size for a fish. For many small fish species (e.g., anchovy, sardines, etc.), even these items (with the exception of chaff) are often too large to be ingested, even though small pieces could sometimes be nibbled off by small fishes. Therefore, the discussion in this section focuses on those fish species large enough to potentially ingest these materials.

The analysis of ingestion effects on fishes is structured around the following feeding strategies:

F.6.4.1.1 Feeding at or Just Below the Surface or Within the Water Column

- **Open-Ocean Predators.** Large, migratory, open-ocean fishes, such as tunas, mahi mahi, sharks, and billfishes, feed on fast-swimming prey in the water column of the Study Area. These fishes range widely in search of unevenly distributed food patches. Smaller military expended materials could be mistaken for prey items and ingested purposefully or incidentally as the fish is swimming. A few of these predatory fishes (e.g., tiger sharks) are known to ingest any type of marine debris that they can swallow, even automobile tires. Some marine fishes, such as tunas, eat plastic fragments, strings, nylon lines, ropes, or even small light bulbs (Choy & Drazen, 2013; Rochman et al., 2015).
- **Open-Ocean Planktivores.** Plankton-eating fishes in the open-ocean portion of the Study Area include anchovies, sardines, flyingfishes, ocean sunfish, manta rays, whale sharks, and basking sharks. These fishes feed by either filtering plankton from the water column or by selectively ingesting larger zooplankton. These planktivores could encounter and incidentally feed on smaller types of military expended materials (e.g., chaff, end caps, pistons) at the surface or in the water column. Giant manta rays are the only ESA-listed species in the Study Area that is an open ocean planktivore, while some species in this group of fishes (e.g., anchovies) constitute a major prey base for many important predators, including tunas, sharks, marine mammals, and seabirds. While not a consumer of plankton, the ocean sunfish eats jellyfish and may consume a decelerator/parachute by accident at or just below the surface in the open ocean. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a decelerator/parachute.

Military expended materials that could potentially affect these types of fish at or just below the surface or in the water column include those items that float or are suspended in the water column for some period of time (e.g., decelerators/parachutes and end caps and pistons from chaff cartridges or flares).

F.6.4.1.2 Fishes Feeding at the Seafloor

- **Bottom Dwelling Predators.** Large predatory fishes near the seafloor are represented by rockfishes, groupers, and jacks, which are typical seafloor predators in the Study Area. These species feed opportunistically on or near the bottom, taking fish and invertebrates from the water column and from the bottom (e.g., crabs, octopus). Bottom-dwelling fishes in the nearshore coasts may feed by seeking prey and by scavenging on dead fishes and invertebrates (e.g., skates, rays, flatfishes, ratfishes).

- **Bottom Dwelling Foragers and Scavengers**. Bottom dwelling fishes may feed by seeking prey and by scavenging on dead fishes and invertebrates. Flatfishes, rays, and some sharks in the Study Area feed along the bottom on small fish and invertebrate prey, which could increase the likelihood of incidental ingestion of marine debris.

Military expended materials that could be ingested by fishes at the seafloor include items that sink (e.g., small-caliber projectiles and casings, fragments from high-explosive munitions).

Potential effects of ingestion on some adult fishes are different than for other life stages (eggs, larvae, and juveniles) because early life stages for some species are too small to ingest any military expended materials except for chaff, which has been shown to have limited effects on fishes in the concentration levels that it is released at (Arfsten et al., 2002; U.S. Department of the Air Force, 1997; U.S. Department of the Navy, 1999). Therefore, with the exception of later stage larvae and juveniles that could ingest microplastics, no ingestion potential effects on early life stages are expected.

Within the context of fish location in the water column and feeding strategies, the analysis is divided into (1) munitions (small- and medium-caliber projectiles, and small fragments from larger munitions); and (2) military expended material other than munitions (chaff, chaff end caps, pistons, decelerators/parachutes, flares, and target fragments).

F.6.4.2 Effects from Military Expended Materials – Munitions

Different types of explosive and non-explosive practice munitions are expended at sea during training and testing activities. This section analyzes the potential for fishes to ingest non-explosive practice munitions and fragments from high explosive munitions.

Types of non-explosive practice munitions generally include projectiles, missiles, and bombs. Of these, only small- or medium-caliber projectiles would be small enough for a large fish to ingest. Small- and medium-caliber projectiles include all sizes up to and including 2.25 inches in diameter. These solid metal materials would quickly move through the water column and settle to the seafloor. Ingestion of non-explosive practice munitions in the water column is possible when shiny fragments of the munitions sink quickly and could be ingested by fast, mobile predators that chase moving prey (e.g., tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas). In addition, these fragments may also be accidentally ingested by fishes that forage on the bottom such as flatfishes, skates, and rays. Types of high explosive munitions that can result in fragments include demolition charges, projectiles, missiles, and bombs. Fragments would result from fractures in the munitions casing and would vary in size depending on the size of the net explosive weight and munitions type; however, typical sizes of fragments are unknown. These solid metal materials would quickly move through the water column and settle to the seafloor. Similar to non-explosive practice munitions described above, ingestion of high-explosive munition fragments by fast-moving mobile predators such tunas, jacks, billfishes, swordfishes, dolphinfishes, mackerel, wahoo, and barracudas in the water column is possible. In the unlikely event that explosive material, high-melting-point explosive (known as HMX), or royal demolition explosive (known as RDX) is exposed on the ocean floor, it would break down in a few hours (U.S. Department of the Navy, 2001b, 2001c). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fish (Lotufo et al., 2010; Price et al., 1998). Fragments are primarily encountered by species that forage on the bottom.

It is possible that expended small-caliber projectiles on the seafloor could be colonized by seafloor organisms and mistaken for prey or that expended small-caliber projectiles could be accidentally or intentionally eaten during foraging. Over time, the metal may corrode or become covered by sediment in some habitats, reducing the likelihood of a fish encountering the small caliber, non-explosive practice munitions.

The potential effects of ingesting foreign objects on a given fish depend on the species and size of the fish. Fish that normally eat spiny, hard-bodied invertebrates may have tougher mouths and digestive systems than fish that normally feed on softer prey. Materials that are similar to the normal diet of a fish would be more likely to be ingested and more easily handled once ingested—for example, by fishes that feed on invertebrates with sharp appendages. These items could include fragments from high-explosives that a fish could encounter on the seafloor. Relatively small or smooth objects, such as small caliber projectiles or their casings, might pass through the digestive tract without causing harm. A small sharp-edged item could cause a fish immediate physical distress by tearing or cutting the mouth, throat, or stomach. If the object is rigid and large (relative to the fish's mouth and throat), it may block the throat or obstruct the flow of waste through the digestive system. An object may be enclosed by a cyst in the gut lining (Danner et al., 2009; Hoss & Settle, 1990). Ingestion of large foreign objects could lead to disruption of a fish's normal feeding behavior, which could be sublethal or lethal.

F.6.4.3 Effects from Military Expended Materials – Other than Munitions

Fishes feed throughout the water column and could mistake many types of marine debris for prey items. Ingesting nonfood items is common among a variety of marine fishes, particularly those that feed on the seafloor (Boerger et al., 2010; Hoss & Settle, 1990; Jackson et al., 2000). Many fishes are also known to accidentally ingest plastic materials, and the extent to which an individual fish might discriminate between a plastic item perceived as prey and an indistinct or less appealing shape is not clear. Once eaten, any type of plastic could cause digestive problems for the fish (Danner et al., 2009). Fishes have been reported to ingest a variety of materials or debris, such as plastic pellets, bags, rope, and line (Hoss & Settle, 1990; Jackson et al., 2000). As discussed above in Section 3.5.3.6 (Ingestion Stressors), some fish species such as the ocean sunfish eat jellyfish and may consume a decelerator/parachute at or just below the surface in the open ocean by accident. Larger filter feeders such as whale sharks, basking sharks, and manta rays could also inadvertently ingest a small or medium decelerator/parachute.

Chaff is used throughout the Study Area. It is composed of an aluminum alloy coating on glass fibers of silicon dioxide and is released or dispensed in cartridges or projectiles that contain millions of fibers. Based on the small size of chaff fibers, fish would likely not confuse the fibers with prey items or purposefully feed on them. However, some fishes could occasionally ingest low concentrations of chaff incidentally while feeding on prey items on the surface, in the water column, or the seafloor. Chaff fiber ingestion is not expected to affect fishes based on the low concentration that could reasonably be ingested and the small size of the chaff fibers. Therefore, exposure to chaff would cause no injury, mortality, or tissue damage to fishes. Potential effects of chaff ingestion by fish are not discussed further. Effects of ingestion of the end caps or pistons associated with chaff cartridges are analyzed together with effects of flares below.

Chaff end caps and pistons sink in saltwater (U.S. Department of the Navy, 1999). Fishes feeding on the where chaff canisters and flares are expended (e.g., range complexes would be more likely to encounter and ingest these items than in other locations. Ingested end caps or pistons could disrupt a fish's feeding behavior or digestive processes. If the item is particularly large relative to the fish ingesting it, the item could become permanently encapsulated by the stomach lining, and potentially lead to starvation and death (Danner et al., 2009; Hoss & Settle, 1990). The highest density of chaff and flare end caps/pistons would be expended in the Southern California Range Complex. Based on the low environmental concentration (Section 3.2, Sediments and Water Quality), it is unlikely that a larger number of fishes would ingest an end cap or piston, much less a harmful quantity. Furthermore, a fish might expel the item before swallowing it. The number of fish potentially affected by ingestion of end caps or pistons would be low based on the low environmental concentration and population-level effects are not expected to occur.

As described above, surface-feeding fishes have little opportunity to ingest end caps or pistons before they sink. However, some of these items could become entangled in dense algal mats near the surface. Predatory open-ocean fishes, such as tunas, dolphinfishes, and billfishes, are attracted to the many small prey species associated with algal mats. While foraging near the floating mats, predatory fishes may incidentally ingest end caps and pistons. The density of these items in any given location would vary based on release points and dispersion by wind and water currents. The number of end-caps and pistons that would remain at or just below the surface in algal mats and potentially available to fish is unknown. Unlike other plastic types of marine debris, end caps and pistons are heavier than water and not expected to float unless they are enmeshed in algal or other floating debris.

Most materials associated with airborne mine neutralization system activities are recovered, but pieces of fiber optic cable may be expended (U.S. Department of the Navy, 2001c). For a discussion of the physical characteristics of these expended materials, where they are used, and the number of activities in each alternative, please see Section 3.0.3.3.5.1 (Wires, Cables, and Nets). Only small amounts of fiber optic cable would be deposited onto the seafloor each year, and the small amount of fiber optic cable expended during training and testing would sink to the seafloor. Highly migratory pelagic predators (e.g., tunas, billfishes, pelagic sharks) would be unlikely to encounter the small, dispersed lengths of fiber optic cable unless they were in the immediate area when the cable was expended. The low number of fiber optic cables expended in the Study Area during this activity makes it unlikely that fishes would encounter any fiber optic cables. Potential effects of fiber optic cable ingestion by fishes are not discussed further.

F.6.5 Secondary Stressors

F.6.5.1 Explosions

Secondary effects on fishes resulting from explosions at the surface, in the water column, or on the bottom would be associated with changes to habitat structure and effects to prey species. Most explosions on the bottom would occur in soft bottom habitat and would displace some amount of sediment, potentially resulting in cratering. However, water movement would redistribute the affected sediment over time. A small amount of sediment would be suspended in the water column temporarily (turbidity), but would resettle to the bottom. Activities that inadvertently result in explosions on or near hard bottom habitat or reefs could break hard structures and reduce the amount of colonizing surface available to encrusting organisms (e.g., corals, sponges). Given the large spatial area of the range complexes compared to the small percentage covered by hard bottom habitat, it is unlikely that most of the small, medium, and large projectiles expended in the Study Area would fall onto this habitat type. Furthermore, these activities are distributed within discrete locations within the Study Area, and the overall footprint of these areas is quite small with respect to the spatial extent of biogenic habitat within the Study Area.

Sinking exercises could also provide secondary effects on deep sea populations. These activities occur in open-ocean areas, outside of the coastal range complexes, with potential direct disturbance or strike effects on deep-sea fishes, as covered in Section 3.6.3.4 (Physical Disturbance and Strike Stressors). Secondary effects on these fishes could occur after the ship hulks sink to the seafloor. Over time, the ship hulk would be colonized by marine organisms that attach to hard surfaces. For fishes that feed on these types of organisms, or whose abundances are limited by available hard structural habitat, the ships that are sunk during sinking exercises could provide an incidental beneficial effect on the fish community (Love & York, 2005; Macreadie et al., 2011).

The alternatives could result in localized and temporary changes to the benthic community during activities that affect fish habitat. Fish habitat could become degraded during activities that would strike the seafloor or introduce military expended materials, bombs, projectiles, missiles, rockets or fragments to the seafloor. During or following activities that affect benthic habitats, fish species may experience loss of available benthic prey at locations in the Study Area where these items might be expended. Additionally, plankton and zooplankton that are eaten by fishes may also be negatively affected by these same expended materials. The spatial area of habitat affected by the Proposed Action would be relatively small compared to the available habitat in the Study Area. However, there would still be vast expanses of habitat adjacent to the areas of habitat effect that would remain undisturbed by the Proposed Action. The majority of the physical and biological features required by steelhead are applicable to freshwater and estuaries (i.e., spawning sites, rearing sites, and migration corridors), and are outside the Study Area. Therefore, there would be no effects associated with secondary stressors.

F.6.5.2 Explosion By-Products

Deposition of undetonated explosive materials into the marine environment can be reasonably well estimated by the known failure and low-order detonation rates of high explosives. Undetonated explosives associated with mine neutralization activities are collected after the activity is complete; therefore, potential effects are assumed to be inconsequential for these training and testing activities, but other activities could result in unexploded munitions and unconsumed explosives on the seafloor. Fishes may be exposed by contact with the explosive, contact with contaminants in the sediment or water, and ingestion of contaminated sediments.

High-order explosions consume most of the explosive material, creating typical combustion products. In the case of royal demolition explosive, 98 percent of the products are common seawater constituents and the remainder is rapidly diluted below threshold effect level. Explosion byproducts associated with high order detonations present no indirect stressors to fishes through sediment or water. However, low order detonations and unexploded munitions present elevated likelihood of effects on fishes.

Indirect effects of explosives and unexploded munitions to fishes via sediment is possible in the immediate vicinity of the munitions. Degradation of explosives proceeds via several pathways discussed in Section 3.2 (Sediments and Water Quality). Degradation products of royal demolition explosive are not toxic to marine organisms at realistic exposure levels (Rosen & Lotufo, 2010). Trinitrotoluene (TNT) and its degradation products affect developmental processes in fishes and are acutely toxic to adults at concentrations similar to real-world exposures (Halpern et al., 2008; Rosen & Lotufo, 2010). Relatively low solubility of most explosives and their degradation products means that concentrations of these contaminants in the marine environment are relatively low and readily diluted. Furthermore, while explosives and their degradation products were detectable in marine sediment approximately 0.15–0.3 m away from degrading munitions, the concentrations of these compounds were not statistically distinguishable from background beyond 1–2 m from the degrading munitions (Section 3.2, Sediments and Water Quality). Taken together, it is likely that various life stages of fishes could be affected by the indirect effects of degrading explosives within a very small radius of the explosive (0.3–2 m).

If a high-explosive munitions does not explode, it would sink to the bottom. In the unlikely event that explosive material, high-melting-point explosive (known as HMX), or royal demolition explosive (known as RDX) is exposed on the ocean floor, it would break down in a few hours (U.S. Department of the Navy, 2001c). High-melting-point explosive or royal demolition explosive would not accumulate in the tissues of fishes (Lotufo et al., 2010; Price et al., 1998). Fish may take up TNT from the water when it is present at high concentrations but not from sediments (Lotufo et al., 2010). The rapid dispersal and dilution of TNT expected in the marine water column reduces the likelihood of a fish encountering high concentrations of TNT to near zero.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the effects of undetonated materials and unexploded munitions on marine life. A summary of this literature which investigated water and sediment quality effects, on a localized scale, from munitions ocean disposal sites and ocean disposed dredge spoils sites is presented in the Sediments and Water Quality section and specifically in Section 3.2.3.1 (Explosives and Explosives Byproducts) and Section 3.2.3.2 (Metals). Findings from these studies indicate that there were no adverse effects on the local ecology from the presence of degrading munitions and there was no bioaccumulation of munitions-related chemicals in local marine species. Therefore, water quality effects from the use of munitions, expended material, or devices would be negligible, would have no long-term effect on water quality, and therefore would not constitute a secondary indirect stressor for fishes.

F.6.5.3 Metals

Certain metals and metal-containing compounds at concentrations above background levels (e.g., cadmium, chromium, lead, mercury, zinc, copper, manganese, and many others) can be toxic to fishes (Wang & Rainbow, 2008). Metals are introduced into seawater and sediments as a result of training and testing activities involving vessel hulks, targets, munitions, batteries, and other military expended materials (Section 3.2, Sediments and Water Quality). Some metals bioaccumulate, and physiological effects begin to occur only after several trophic transfers concentrate the toxic metals (U.S. Department of the Navy, 2012a). Indirect effects of metals on fish via sediment and water involve concentrations several orders of magnitude lower than concentrations achieved via bioaccumulation. Fishes may be exposed by contact with the metal, contact with contaminants in the sediment or water, and ingestion of contaminated sediments. Concentrations of metals in seawater are orders of magnitude lower than concentrations in marine sediments. It is extremely unlikely that fishes would be indirectly affected by toxic metals via the water.

F.6.5.4 Chemicals

Several Navy training and testing activities introduce potentially harmful chemicals into the marine environment, principally flares and propellants for rockets, missiles, and torpedoes. Polychlorinated biphenyls are discussed in Section 3.2 (Sediments and Water Quality), but there is no additional risk to fish because the Proposed Action does not introduce this chemical into the Study Area and the use of polychlorinated biphenyls has been nearly zero since 1979. Properly functioning flares, missiles, rockets, and torpedoes combust most of their propellants, leaving benign or readily diluted soluble combustion byproducts (e.g., hydrogen cyanide). Operational failures allow propellants and their degradation products to be released into the marine environment.

The greatest risk to fishes from flares, missiles, and rocket propellants is perchlorate, which is highly soluble in water, persistent, and affects metabolic processes in many plants and animals. Fishes may be exposed by contact with contaminated water or ingestion of re-suspended contaminated sediments. Since perchlorate is highly soluble, it does not readily adsorb to sediments. Therefore, missile and rocket fuels pose no risk of indirect effect on fishes via sediment. In contrast, the principal toxic components of torpedo fuel, propylene glycol dinitrate and nitrodiphenylamine, adsorbs to sediments, have relatively low toxicity, and are readily degraded by biological processes (Section 3.2, Sediments and Water Quality). It is conceivable that various life stages of fishes could be indirectly affected by propellants via sediment in the immediate vicinity of the object (e.g., within a few inches), but these potential effects would diminish rapidly as the propellant degrades.

F.6.5.5 Other Materials

Some military expended materials (e.g., decelerators/parachutes) could become remobilized after their initial contact with the seafloor (e.g., by waves or currents) and could pose an entanglement or ingestion hazard for fishes. For example, in some bottom types without strong currents, hard-packed sediments, and low biological productivity, items such as projectiles might remain intact for some time before becoming degraded or broken down by natural processes. These potential effects may cease only (1) when the military expended materials are too massive to be mobilized by typical oceanographic processes, (2) if the military expended materials become encrusted by natural processes and incorporated into the seafloor, or (3) when the military expended materials become permanently buried. In this scenario, a decelerator/parachute could initially sink to the seafloor, but then be transported laterally through the water column or along the seafloor, increasing the opportunity for entanglement. In the unlikely event that a fish would become entangled, injury or mortality could result. In contrast to large decelerators/parachutes, other devices with decelerators such as sonobuoys are typically used in deep open ocean areas. These areas are much lower in fish numbers and diversity, so entanglement hazards are greatly reduced for commercially and recreationally targeted species (ex. tuna, swordfish, etc.), as well as mesopelagic prey of other species. The entanglement stressor would eventually cease to pose an entanglement risk as it becomes encrusted or buried.

F.7 Marine Mammals

F.7.1 Energy Stressors

F.7.1.1 Effects from In-Water Electromagnetic Devices

There has been renewed interest in this topic of inquiry given the potential for electromagnetic fields generated by undersea power cables to possibly affect geo-navigation in migrating marine mammals (Gill et al., 2014; Kremers et al., 2016b; Kremers et al., 2014; Zellar et al., 2017). Horton et al. (2017) have indicated that future experiments involving empirical observation of free-ranging animals are still required for there to be sufficient evidence demonstrating causal relations between marine mammal movement decisions and environmental cues such as Earth's magnetic field.

Most of the early research investigated the possible correlations of where live-stranding locations occurred to determine if there was an associated local variation in Earth's magnetic field (Kirschvink, 1990; Klinowska, 1985; Walker et al., 1992). Species included long-finned and short-finned pilot whales, striped dolphin, Atlantic spotted dolphin, Atlantic white-sided dolphin, fin whale, common dolphin, harbor porpoise, sperm whale, and pygmy sperm whale, which had live stranding locations that correlated with areas where the earth's magnetic field was locally weaker than surrounding areas (Kirschvink, 1990). These statistical associations for locally weaker areas represented a total intensity variation of less than 0.05 microtesla in the magnetic field (Kirschvink et al., 1986). While this correlation seemed to have also been demonstrated for bottlenose dolphins in the Atlantic (Kirschvink et al., 1986), there was no correlation found in the Pacific (Kirschvink, 1990). Subsequent research regarding fin whale sightings over the continental shelf off the northeastern United States was consistent with the findings involving stranded fin whales (Kirschvink, 1990), supporting the hypothesis that fin whales possess a magnetic sense and that they use it to migrate (Walker et al., 1992). Bureau of Ocean Energy Management (2011) reviewed available information on electromagnetic and magnetic field sensitivity of marine organisms (including marine mammals) for effect assessment of offshore wind farms for the U.S. Department of the Interior and concluded there is no evidence to suggest any magnetic sensitivity for sea lions, fur seals, or sea otters (Bureau of Ocean Energy Management, 2011). However, the researchers concluded there was behavioral, anatomical, and theoretical evidence indicating that cetaceans sense magnetic fields.

Anatomical evidence suggests the presence of magnetic material in the brain (Pacific common dolphin, Dall’s porpoise, bottlenose dolphin, Cuvier’s beaked whale, and the humpback whale) and in the tongue and lower jawbones (harbor porpoise) (Bauer et al., 1985; Kirschvink, 1990). Zoeger et al. (1981) found what appeared to be nerve fibers associated with the magnetic material in a Pacific common dolphin and proposed that it may be used as a magnetic field receptor. Electrosensitivity was found in the Guiana dolphin (Czech-Damal et al., 2011). Kuzhetsov (1999) conducted experiments exposing bottlenose dolphins to permanent magnetic field intensities of 32, 108, and 168 microteslas and showed both behavioral and physiological reactions during 79 percent, 63 percent, and 53 percent of the trials, respectively (as summarized in Bureau of Ocean Energy Management (2011)). Behavioral reactions included sharp exhalations, acoustic activity, and movement, while physiological reactions included a change in heart rate. Kremers et al. (2014) conducted another experiment to observe the spontaneous reactions of captive bottlenose dolphins from a magnetized device compared to a demagnetized device. Results from this experiment confirmed that dolphins are capable of perceiving magnetic fields from a distance of more than 1.5 m from the 1.2 tesla magnetic strength device; creating a magnetic field with a strength of approximately 0.051 to 0.240 tesla between 2 to 5 cm from the source (Kremers et al., 2014). The dolphins approached the magnetized device with shorter latency compared to the demagnetized device that was identical in form and density and otherwise undistinguishable through echolocation (Kremers et al., 2014). The findings also suggest that dolphins may be able to discriminate between two items based on their magnetic properties (Kremers et al., 2016a). It is still unclear whether magnetic fields are attractive or repulsive to dolphins (Kremers et al., 2016a; Kremers et al., 2014) and further studies on the magnetic perception threshold on dolphin behavior need to be conducted (Kremers et al., 2016a).

Although it is not fully understood, based on the available evidence described above, it is probable that marine mammals use Earth’s magnetic field for orientation or migration (Walker et al., 1992). If a marine mammal was in proximity of an in-water electromagnetic field source associated with Navy training and testing, emitting a field strong enough to be detected, and that animal is sensitive to the exposure, it is conceivable that this electromagnetic field could have an effect on a marine mammal, primarily affecting that animal’s navigation.

F.7.1.2 Effects from High-Energy Lasers

As discussed in Section 3.0.3.3.3.3 (Lasers) in the 2018 Hawaii-Southern California Training and Testing (HSTT) EIS/OEIS, high-energy laser weapons are designed to disable surface targets, rendering them immobile. The primary effect from high-energy lasers would be from the laser beam striking a marine mammal at or near the water's surface, which could result in injury or death.

Marine mammals could be exposed to a laser only if the beam missed the target. Should the laser strike the sea surface, individual marine mammals at or near the surface could be exposed. The potential for exposure to a high-energy laser beam decreases as the water depth increases. Most marine mammals are unlikely to be exposed to laser activities due to mitigation measures discussed in Chapter 5 (Mitigation).

F.7.2 Physical Disturbance and Strike Stressors

F.7.2.1 Effects from Vessels and In-Water Devices

Surface vessels can be a source of acute and chronic disturbance for cetaceans (Au & Green, 2000; Bejder et al., 2006; Hewitt, 1985; Lusseau et al., 2009; Magalhães et al., 2002; Nowacek et al., 2007; Nowacek et al., 2004b; Richter et al., 2006; Richter et al., 2003; Schoeman et al., 2020; Watkins, 1986; Würsig & Richardson, 2009). Studies have established that cetaceans engage in avoidance behavior when surface vessels move toward them. Overall, strike avoidance success is dependent on a marine mammal’s ability to identify and locate the vessel from its radiated sound and the animal’s ability to maneuver away from the vessel in time.

Various research findings report that mysticetes have variable responses to vessels dependent on the context (Nowacek et al., 2004a; Richardson et al., 1995; Watkins, 1986). Similarly, odontocetes have also demonstrated responses to vessels. One study showed that harbor porpoises in a net-pen displayed behavioral responses (increasing swim speed or repeated alternating surfacing and diving behaviors [i.e., porpoising]) to the high-frequency components of vessel noise at long ranges (more than 1,000 m) in shallow waters (Dyndo et al., 2015). These distances correspond to where radiated noise would be more likely to elicit the response, rather than physical presence of the vessel (Dyndo et al., 2015; Palka & Hammond, 2001). Conversely, another study demonstrated that physical vessel presence, and not just noise, was associated with a short-term reduction in foraging activity in bottlenose dolphins (Pirotta et al., 2015). It is noteworthy that the dolphins associated with this report were exposed primarily to commercial and leisure boat traffic, not related to military vessel activities. Even repeated exposures from increasing vessel traffic in the same area resulting in increased responses to the disturbance may not be biologically significant. Mathematic modeling has predicted that bottlenose dolphin population dynamics would remain unchanged from a sixfold increase in vessel traffic (70 to 470 vessels per year) as dolphins are able to compensate for increased disturbance levels with little to no effects on health and vital rates (New et al., 2013). Aside from the potential for an increased risk of strike addressed below, physical disturbance from vessel use is not expected to result in more than a short-term behavioral response.

Hauled-out pinnipeds are also disturbed when approached at close distance, although the research indicates this is somewhat context-dependent. For example, one study showed that harbor seals were disturbed by tourism-related vessels, small boats, and kayaks that stopped or lingered by haulout sites, but that the seals “do not pay attention to” passing vessels at closer distances (Johnson & Acevedo-Gutiérrez, 2007). Pinnipeds in the water generally appear less responsive (Richardson et al., 1995) than those at haulout sites. Walrus and polar bears have also appeared to be attracted to vessels at times (Harwood et al., 2005) and manatees have displayed vulnerabilities to vessel impacts (Nowacek et al., 2004b).

In some circumstances, marine mammals respond to vessels with the same behavioral repertoire and tactics they employ when they encounter predators. It is not clear what environmental cue or cues marine animals might respond to; they may include the sounds of water being displaced by the ships, the sounds of the ships' engines, or a combination of environmental cues surface vessels produce while they transit. For example, in one study, North Atlantic right whales showed little overall reaction to the playback of sounds of approaching vessels, but they did respond to a novel sound by swimming strongly to the surface, which may increase their risk of strike (Nowacek et al., 2004a).

Vessel strikes from commercial, recreational, and Navy vessels are known to have resulted in serious injury and occasional fatalities to cetaceans (Abramson et al., 2011; Berman-Kowalewski et al., 2010; Calambokidis, 2012; Douglas et al., 2008; Laggner, 2009; Lammers et al., 2003; Van der Hoop et al., 2013; Van der Hoop et al., 2012). Reviews of the literature on ship strikes mainly involve strikes between commercial vessels and whales (Jensen & Silber, 2004; Laist et al., 2001). Juvenile whales of some species may be particular vulnerable to vessel strikes due to their particular habitat use and surface foraging behavior in nearshore waters, where smaller vessel number are higher (Stepanuk et al., 2021).

Vessel speed, size, and mass are all important factors in determining potential impacts of a vessel strike to marine mammals (Conn & Silber, 2013; Gende et al., 2011; Silber et al., 2010; Vanderlaan & Taggart, 2007; Wiley et al., 2016). For large vessels, speed and angle of approach can influence the severity of a strike. Based on modeling conducted by Silber et al. (2010), researchers found that whales at the surface experienced impacts that increased in magnitude with the ship's increasing speed. Another study found that there was a 3.4-fold decrease in close encounters between their research vessel and humpback whales when they traveled at speeds of 12.5 knots or less as opposed to greater than 12.5 knots (Currie et al., 2017).

F.7.2.1.1 Mysticetes

Vessel strikes have been documented for almost all of the mysticete species (Van der Hoop et al., 2012). This includes blue whales (Berman-Kowalewski et al., 2010; Calambokidis, 2012; Van Waerebeek et al., 2007), fin whales (Douglas et al., 2008; Van Waerebeek et al., 2007), North Atlantic right whales (Firestone, 2009; Fonnesbeck et al., 2008; Vanderlaan et al., 2009; Wiley et al., 2016) sei whales (Felix & Van Waerebeek, 2005; Van Waerebeek et al., 2007), Bryde's whales (Felix & Van Waerebeek, 2005; Van Waerebeek et al., 2007), minke whales (Van Waerebeek et al., 2007), humpback whales (Douglas et al., 2008; Lammers et al., 2003; Van Waerebeek et al., 2007), and bowhead whales (Halliday, 2020). Generally, mysticetes are larger than odontocetes and are not able to maneuver as well as odontocetes to avoid vessels. In addition, mysticetes do not typically aggregate in large groups and are therefore difficult to visually detect from the water surface.

Research suggests that the increasing noise in the ocean has made it difficult for whales to detect approaching vessels, which has indirectly raised the risk of vessel strike (Elvin & Taggart, 2008). For example, North Atlantic right whales are documented to show little overall reaction to the playback of sounds of approaching vessels, suggesting that some whales perform only a last-second flight response (Nowacek et al., 2004a). Some individuals may become habituated to low-frequency sounds from shipping and fail to respond to an approaching vessel (National Marine Fisheries Service, 2008b). Because surface activity includes feeding, breeding, and resting, whales may be engaged in this activity and not notice an approaching vessel. Acoustic shadows may also form ahead of a moving vessel, where radiated ship noise levels approach or fall below ambient noise and therefore would be hard to detect if an animal is directly ahead of the ship (Gerstein et al., 2005).

On the other hand, the lack of an acoustic cue of vessel presence can be detrimental as well. One study documented multiple cases where humpback whales struck anchored or drifting vessels; in one case a humpback whale punched a 1.5 m hole through the hull of an anchored 22 m wooden sailboat, and another instance a humpback whale rammed a powered down 10 m fiberglass sailboat (Neilson et al., 2012). These results suggest that either the whales did not detect the vessel, or they intentionally struck it. In this study, vessel strikes to multiple cetacean species were included in the investigation; however, humpback whales were the only species that displayed this type of interaction with an unpowered vessel.

Another study found that 79 percent of reported strikes between sailing vessels and cetaceans occurred when the vessels were under sail, suggesting it may be difficult for whales to detect the faint sound of sailing vessels (Ritter, 2012). However, in some instances, avoidance behavior has been observed even after exposure to noise. A blue whale was observed in a near strike with a ship while the whale was tagged with a tag that collected depth information (Szesciorka et al., 2019). A 263 m container ship approached the whale while traveling at 11.3 knots and came within 93 m of the whale while the whale was at a depth of 67.5 m ascending from a foraging dive. The whale slowed its ascent and switched to a descent dive, surfacing three minutes later. This incident took place in Southern California, and prior to the near strike with the ship, the blue whale had been exposed to simulated mid-frequency (3 to 4 kHz) active sonar (Southall et al., 2019), which ended 62 min prior to the observation presented here.

Vessel strikes are a primary threat to North Atlantic right whale survival (Firestone, 2009; Fonnesbeck et al., 2008; Knowlton & Brown, 2007; Nowacek et al., 2004a; Vanderlaan et al., 2009). Studies of North Atlantic right whales tagged in April 2009 on the Stellwagen Bank feeding grounds found that they spent most of their time at a depth of 6.5 feet (ft.), which makes them less visible at the water's surface (Bocconcelli, 2009; Parks & Wiley, 2009). Between 2017 and 2023, 12 North Atlantic right whales were confirmed to have been killed by vessel strikes, and two more are considered to have serious injuries as the result of vessel strike (Koubrak et al., 2021; Kowarski et al., 2020; National Marine Fisheries Service, 2023).

Mysticetes that occur within the Study Area have varying patterns of occurrence and distribution, which overlap with areas where vessel use associated with Navy military readiness activities would occur. For example, humpback whales that utilize the waters of the Chesapeake Bay near Naval Station Norfolk were found to spend considerable time (82 percent) engaged in foraging behavior at or near the mouth of the bay in close proximity to or directly in the shipping channel (Aschettino et al., 2020). Most of these animals were found to be juveniles, so there may be higher risk in younger animals who also have less experience maneuvering around vessels (Aschettino et al., 2020). Age-specific differences in habitat use compared to vessel density has been found in other areas within the Study Area as well (Stepanuk et al., 2021).

Risk of vessel strikes may increase depending on behavior. Increases in both nighttime foraging of some species and ship traffic overall contributes to increased risk of strike in some areas (Caruso et al., 2021). North Atlantic right whale mother-calf pairs spend 45–80 percent of their time surface resting or near-surface feeding during the first nine months of the calf's life (Cusano et al., 2019).

F.7.2.1.2 Odontocetes

Odontocetes that occur within the Study Area have varying patterns of occurrence and distribution, which overlap with areas where vessel use associated with Navy military readiness activities would occur. Available literature suggests based on their smaller body size, maneuverability, larger group sizes, and hearing capabilities, odontocetes are not as likely to be struck by a vessel as mysticetes. When generally compared to mysticetes, odontocetes are more capable of physically avoiding a vessel strike, and, since some species occur in large groups, they are more easily seen when they are close to the water surface.

In general, odontocetes move quickly and seem to be less vulnerable to vessel strikes than other cetaceans; however, most small whale and dolphin species have at least occasionally suffered from vessel strikes, including killer whale (Van Waerebeek et al., 2007; Visser & Fertl, 2000), short-finned and long-finned pilot whales (Aguilar et al., 2000; Van Waerebeek et al., 2007), bottlenose dolphin (Bloom & Jager, 1994; Van Waerebeek et al., 2007; Wells & Scott, 1997), white-beaked dolphin (Van Waerebeek et al., 2007), short-beaked common dolphin (Van Waerebeek et al., 2007), spinner dolphin (Camargo & Bellini, 2007; Van Waerebeek et al., 2007), striped dolphin (Van Waerebeek et al., 2007), Atlantic spotted dolphin (Van Waerebeek et al., 2007), and pygmy sperm whales (*Kogia breviceps*) (Van Waerebeek et al., 2007). Beaked whales documented in vessel strikes include Arnoux's beaked whale (Van Waerebeek et al., 2007), Cuvier's beaked whale (Aguilar et al., 2000; Van Waerebeek et al., 2007), and several species of *Mesoplodon* (Van Waerebeek et al., 2007).

However, evidence suggests that beaked whales may be able to hear the low-frequency sounds of large vessels and thus potentially avoid strike (Ketten, 1998). Sperm whales may be exceptionally vulnerable to vessel strikes as they spend extended periods of time "rafting" at the surface to restore oxygen levels within their tissues after deep dives (Jaquet & Whitehead, 1996; Watkins et al., 1999). Based on hearing capabilities and dive behavior, sperm whales may not be capable of successfully completing an escape maneuver, such as a dive, in the time available after perceiving a fast-moving vessel. This supports the suggestion that vessel speed is a critical parameter for sperm whale strike risks (Gannier & Marty, 2015). Data on vessel strikes of smaller cetaceans are generally scarce likely due, at least in part, to a reporting bias rather than strikes being less frequent (Schoeman et al., 2020).

F.7.2.1.3 Pinnipeds

Ship strikes were not reported as a global threat to pinniped populations by Kovacs et al. (2012). Pinnipeds in general appear to suffer fewer impacts from vessel strikes than do cetaceans or sirenians. This may be due, at least in part, to the time they spend on land resting and breeding, and their high maneuverability in the water. A review of seal stranding data from Cape Cod, Massachusetts, from 1999 to 2004 found that 622 pinniped strandings were recorded by the Cape Cod Stranding Network. Of these 622 strandings, 11 (approximately 2 percent) were found to be caused by boat strikes. Mortalities of pinnipeds (specifically harbor seals and gray seals) have initially been attributed to injuries sustained from ducted propellers on vessels such as workboats, tugs, and other support vessels (Bexton et al., 2012). However, further investigations have lead researchers to conclude that injuries that appeared to be the result of propellers were actually due to gray seal predation, cannibalism, and infanticide (Brownlow et al., 2016). Studies done in other areas have found similarly low trends—one study in the Salish Sea only found 27 instances of vessel strike out of 3,633 cases, with the majority of these cases found in pups (Olson et al., 2021).

F.7.2.1.4 Manatees

West Indian manatees respond to vessel movement via acoustic and possibly visual cues by moving away from the approaching vessel, increasing their swimming speed, and moving toward deeper water (Miksis-Olds et al., 2007; Nowacek et al., 2004b). The degree of the response varies with the individual manatee and may be more pronounced in deeper water where they are more easily able to locate the direction of the approaching vessel (Nowacek et al., 2004b). This disturbance is a temporary response to the approaching vessel. West Indian manatees have also been shown to seek out areas with a lower density of vessels (Buckingham et al., 1999). West Indian manatees exhibit a clear behavioral response to vessels within distances of 25 to 50 m (Nowacek et al., 2004b). Rycyk et al. (2018) found pronounced behavioral responses in tagged manatees when vessels passed within 10 m of the animal. While vessel speed did not have an effect on the occurrence, type, or number of behavioral changes observed in tagged manatees, results showed that manatees have more time to respond and changed their behavioral earlier when vessels approached slowly compared to vessels transiting on a plane at high speeds (approximately 20 miles per hour or greater) (Rycyk et al., 2018). Vessel traffic and recreation activities that disturb West Indian manatees may cause them to leave preferred habitats and may alter biologically important behaviors such as feeding, suckling, or resting (Haubold et al., 2006). Manatees use nearshore boat channels and open water fairways as migratory and travel corridors, but have been shown to use the nearshore channel more frequently (Cloyed et al., 2019).

In addition to disturbance, West Indian manatees are particularly susceptible to vessel strikes (both strikes with the hull and propeller strikes) because they hover near the surface of the water, move very slowly, and spend most of their time in inshore waters where vessel traffic tends to be more concentrated (Calleson & Frohlich, 2007; Gerstein, 2002; Haubold et al., 2006; Runge et al., 2007). Recent modeling suggests that approximately 96 percent of adults, 70 percent of subadults, and 34 percent of calves have watercraft-related scars (Bassett et al., 2020). Vessel strikes are the direct agent of most human-caused deaths to adult West Indian manatees (Rommel et al., 2007), accounting for approximately 21 percent of all manatee deaths from 1974 to 2016 (Bassett et al., 2020), and 15 percent of all manatee injuries recorded in Florida between 2008 and 2012 (U.S. Fish and Wildlife Service, 2014). An analysis of a five-year subset (2000 to 2004) of historical mortality data suggests that a disproportionate number of propeller-caused watercraft-related mortalities could be attributed to propeller diameters greater than or equal to 17 inches (in.), suggesting that these were caused by watercraft greater than 40 ft. (Rommel et al., 2007). The USFWS indicates that manatees are probably struck by smaller watercraft more often, but the likelihood of mortality is dependent on the force of strike, which is a factor of the speed and size of the vessel. Martin et al. (2015) found that the expected number of manatee and boat encounters in a given area increased with vessel speed and distance traveled by the boat. The findings in Rycyk et al. (2018) on manatee response time to slower vessels suggest strikes with slow-moving vessels are less likely to be lethal compared to high-speed vessels.

Not all strikes are fatal, as evidenced by the fact that most West Indian manatees in Florida bear scars from previous boat strikes (Rommel et al., 2007). In fact, the Manatee Individual Photo-identification System identifies more than 3,000 Florida manatees by scar patterns mostly caused by boats, and most cataloged manatees have more than one scar pattern, indicative of multiple boat strikes (81 *Federal Register* 1000–1026, January 8, 2016). Non-lethal injuries may reduce the breeding success of females (Haubold et al., 2006) and may lower a manatee’s immune response (Halvorsen & Keith, 2008).

F.7.2.2 Effects from Aircraft and Aerial Targets

Effects from aircraft and aerial targets are not applicable to marine mammals because they do not occur in airborne environments and will not be analyzed further in this section.

F.7.2.3 Effects from Military Expended Materials

The primary concern is the potential for a marine mammal to be hit with military expended material at or near the water’s surface, which could result in injury or death. While disturbance or strike from an item falling through the water column is possible, it is not very likely because the objects generally sink slowly through the water and can be avoided by most marine mammals. Therefore, the discussion of military expended material strikes focuses on the potential of a strike at the surface of the water.

While no strike from military expended materials has ever been reported or recorded, the possibility of a strike still exists. Therefore, the potential for marine mammals to be struck by military expended materials was evaluated using statistical probability modeling to estimate potential direct strike exposures to a marine mammal under a worst-case scenario. Specific details of the modeling approach, including model selection and calculation methods, are presented in Appendix I (Military Expended Materials and Direct Strike Impact Analysis).

F.7.2.4 Effects from Seafloor Devices

The only seafloor device used during military readiness activities that has the potential to strike a marine mammal at or near the surface is an aircraft-deployed mine shape, which is used during aerial mine laying activities. These devices are identical to non-explosive practice bombs, and, therefore, the analysis of the potential effects from those devices is covered in Section F.7.2.3 (Effects from Military Expended Materials) and are not further analyzed in this section.

F.7.2.5 Effects from Pile Driving

Impact pile driving and vibratory pile removal as described in Chapter 2 (Description of Proposed Action and Alternatives) and Table 2.3-2 (Proposed Training Activities), was considered as a potential physical disturbance and strike stressor. This section addresses the physical presence of a temporary pier structure as a potential physical disturbance stressor and the potential for direct strike during pile driving.

Under Alternative 1 for training, pile driving use would occur during port repair activities at Naval Base Ventura County Port Hueneme.

Given the nearshore locations for this training activity and the temporary nature of the structures, it is not likely that marine mammals would experience physical disturbance from the presence of the temporary pier structure. Furthermore, it is not likely that any marine mammal would be struck by a piling during installation. Mitigation measures discussed in Chapter 5 (Mitigation) would be conducted to further reduce any potential for effects.

F.7.3 Entanglement Stressors

This analysis includes the potential effects from three types of military expended materials: (1) wires and cables and (2) decelerators/parachutes. These materials, if encountered, may have the potential to entangle marine mammals in the Study Area at the surface, in the water column, or along the seafloor. Since potential effects depend on how a marine mammal encounters and reacts to items that pose an entanglement risk, the following subsections discuss research relevant to specific groups or species. Risk factors such as animal size, sensory capabilities, and foraging methods are also considered in the potential risk for entanglement. Most entanglements discussed are attributable to marine mammal encounters with fishing gear or other non-military materials that float or are suspended at the surface. Entanglement events are difficult to detect from land or from a boat as they may occur at considerable distances from shore and typically take place underwater. Smaller entangled animals are inherently less likely to be detected than larger ones, but larger animals may subsequently swim off while still entangled, towing lines or fishing gear behind them. Therefore, the likelihood of witnessing an entanglement event is typically low (Benjamins et al., 2014). However, the properties and size of these military expended materials, as described in the 2018 HSTT EIS/OEIS Section 3.0.3.3.5 (Entanglement Stressors) and Section 3.0.3.6.4 (Conceptual Framework for Assessing Effects from Entanglement), makes entanglement unlikely.

Since there has never been a reported or recorded instance of a marine mammal entangled in military expended materials (Henry et al., 2016; National Oceanic and Atmospheric Administration Marine Debris Program, 2014a), the Navy considered the available literature and reports on entanglement. These reports indicate that active and derelict fishing gear is the predominant cause of entanglement. The reason for this, and the ways that fishing gear may be different from military expended materials, are as follows: (1) fishing gear is most often used in areas of high productivity where whales may congregate and feed; whereas military expended materials are generally used in broad, diverse, open-ocean areas and expenditures are not concentrated; (2) fishing gear is designed to trap/entangle marine life and are made with a high breaking strength to withstand prolonged use in the ocean environment; military expended materials are not designed to persist in the ocean environment for long periods of time and are not designed to entangle or capture marine life; and (3) fishing gear and ropes are designed to float or be suspended in the water column for long periods of time, whereas most military expended materials sink immediately and rapidly.

F.7.3.1 Mysticetes

Mysticete species with documented entanglement reports include humpback whales, North Atlantic right whales, Rice's whales, minke whales, and bowhead whales (Cassoff et al., 2011; National Oceanic and Atmospheric Administration Marine Debris Program, 2014a). Aside from Rice's whales, the aforementioned species have records directly linking entanglement to marine debris as opposed to active fishing gear (Baulch & Perry, 2014; Laist, 1997). It has been estimated that a minimum of 52 percent and a maximum of 78 percent of whales have been non-lethally entangled in their lifetime in some populations (Neilson et al., 2009). In 2020, there were 25 reports of live entangled large whales along the east coast of the United States, and 33 in 2019 (National Marine Fisheries Service, 2022a, 2022b).

Entanglement of many large whales most often begins with rope being caught in its baleen plates. Based on feeding adaptations for mysticetes, oral entanglement may pose one of the greatest threats to survival, due to impaired foraging and possibly loss of function of the hydrostatic seal (formed when upper and lower lips come together and keep the mouth closed), requiring the whale to expend energy to actively keep the mouth closed during swimming (Cassoff et al., 2011). Impaired foraging could lead to deterioration of health, making the animal more susceptible to disease or eventual starvation over a long period of time, or chronic poor body condition which could result in suppressions to growth, age of sexual maturation and calving rates (Christiansen et al., 2020).

Compounding the issue, trailing lengths of rope or line may become wrapped around the animal's appendages as it struggles to free itself (Kozuck, 2003), limiting the animal's mobility and increasing drag. This reduced mobility can also reduce foraging success or even limit the animal's ability to surface. Notably, the single acute cause of entanglement mortalities has been associated with drowning from multiple body parts being entangled (Cassoff et al., 2011). Even if a whale is freed of an entanglement, the recovery time is estimated to be an average of 1.3–3 months (Moore et al., 2021; van der Hoop et al., 2017), extending the sub-lethal effects of an entanglement.

Common sources of entanglements for mysticetes include line and net fragments attached through the mouth or around the tail and flippers (National Oceanic and Atmospheric Administration Marine Debris

Program, 2014a). Rope diameter and breaking strengths may also determine an animal's ability to break free from entanglement. Increased rope strength has been found to be positively correlated with injury severity in right whales, but not for humpback whales (Knowlton et al., 2016). Minke whales were also found entangled in lower breaking strength ropes (10.47 kilonewtons [2,617 pound (lb.)-force]) than both humpback and right whales (17.13 and 19.30 kilonewtons [3,851 and 4,339 lb.-force], respectively) (Knowlton et al., 2016). These are significantly greater than the breaking strength of torpedo guidance wires (maximum 42 lb.-force) as described in the 2018 HSTT EIS/OEIS's Section 3.0.3.3.5.1 (Wires and Cables). Entanglement would be more likely for materials with similar physical properties as those described above.

In the western North Atlantic, entanglement in fishing gear is a known cause of humpback whale injury and mortality, with all components of both pot and gillnet gear documented during 30 separate humpback whale entanglement events (Johnson et al., 2005). This study also found one entanglement event involving a vessel anchor line rather than fishing gear. Overall, between 6 and 26 percent (average 12 percent) of the population exhibits evidence of new entanglement injuries every year (Robbins, 2009), though the proportion of entanglements due to fishing gear is unknown. Available data indicate that males typically have more entanglement scars than females and may become entangled more frequently. Juvenile whales were found to have a higher rate of entanglement and be more at risk of serious injury and mortality when entangled than mature animals of the same species (Robbins, 2009, 2010).

Military expended material is expected to sink to the ocean floor. It is possible that marine mammals could encounter these items within the water column as they sink to the bottom. Less buoyant items that sink faster are not as likely to become entangled with a marine mammal compared to more buoyant materials that would sink slower to the floor. Mysticetes that occupy the water column or skim feed along the water surface would have to encounter a military expended material at the same time and location it is either expended or as it sinks.

Almost 3 percent of all right whale sightings between 1980 and 2016, and over half of all cataloged North Atlantic right whales (58 percent) have been observed with seafloor sediment on their bodies, which suggests these whales make frequent contact with the seafloor (Hamilton & Kraus, 2019). Mysticete species that feed near or at the bottom in the areas where activities are conducted that result in military expended materials could encounter items that have already sunk and, therefore, do not have to be present at the precise time when items are expended.

F.7.3.2 Odontocetes

Odontocete species with documented records of marine debris entanglement, excluding fishing gear, are the sperm whale, bottlenose dolphin, harbor porpoise, and Dall's porpoise (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a). Bottlenose dolphins are the most commonly entangled odontocete, with most entanglements involving monofilament line, net fragments, and rope attached to appendages (National Oceanic and Atmospheric Administration Marine Debris Program, 2014a). Heezen (1957) reported two confirmed instances of sperm whales entangled in the slack lengths of telegraph cable near cable repair sites along the seafloor. These whales likely became entangled while feeding along the bottom, as the cables were found wrapped around the jaw. Other sperm whale entanglements in gill nets have been reported, resulting in various behavioral responses, injuries and in some cases, mortalities (Haase & Felix, 1994; Jacobsen et al., 2010; Pace et al., 2008). Juvenile harbor porpoises exposed to 0.5-in. diameter white nylon ropes in both vertical and horizontal planes treated the ropes as barriers, more frequently swimming under than over them. However, porpoises feeding on fish in the area crossed the ropes more frequently and became less cautious, suggesting that rope poses a greater risk in a feeding area than in a transit area. For harbor porpoises feeding along the bottom, rope suspended near the seafloor is more likely to entangle than rope higher in the water column given the animals' natural tendency is to swim beneath barriers (Kastelein et al., 2005).

F.7.3.3 Pinnipeds

Entanglement is considered a serious threat to several populations of pinnipeds (Kovacs et al., 2012); 67 percent of pinniped species have been recorded as entangled (Kuhn et al., 2015). Younger pinnipeds appear to be more prone to entanglement than adults (Hofmeyr et al., 2006; Page et al., 2004). Seals can get entangled in nets and fishing line when young and then grow with the lines wrapped around their necks or appendages, causing deep wounds and eventually death. Death may occur by strangulation or severing of the arteries (Derraik, 2002). Between 2004 and 2008, the annual mean entanglement rate for gray seals at a haul-out site in Cornwall (in the United Kingdom) ranged from 3.6 to 5 percent, and mortality rates were likely higher for entangled animals (Allen et al., 2012). Gray and harbor seals also become entangled and drown in the U.S. Northeast Sink Gillnet Fishery (Johnston et al., 2015).

F.7.3.4 Polar Bear

In a review conducted by (Kühn & Van Franeker, 2020) on the interaction between marine debris and wildlife, only one occurrence of entanglement in polar bears was documented, but no further details regarding the material was provided.

F.7.3.5 West Indian Manatee

Entanglements have been documented for manatees (Beck & Barros, 1991; Forrester et al., 1975; O'Shea et al., 1985). Manatee foraging behaviors may predispose them to entanglement with fishery gear due to their tactile nature, meaning they need to be in close proximity or physically touching an object to gain extensive information about it (Adimey et al., 2014). In addition, manatees have limited abilities to detect finer objects, such as monofilament, until they have already come into contact with it, leading to an increased risk of entanglement (Bauer et al., 2012).

Fishery gear interactions with Florida manatees were analyzed from stranding records collected between 1997 and 2009 and results found that approximately 8 percent of the manatee cases were identified as fishery gear interactions (Adimey et al., 2014). Of the 380 reported cases, 76 percent consisted of hook and line interactions and 22 percent were from trap pot gear (Adimey et al., 2014).

F.7.4 Ingestion Stressors

F.7.4.1 Mysticetes

Since baleen whales feed by filtering large amounts of water, they likely encounter and consume plastic debris at higher rates than other marine animals (National Oceanic and Atmospheric Administration Marine Debris Program, 2014b). Species that feed at the surface or in the water column include blue, fin, Bryde's, minke, and sei whales. While humpback whales may feed by lunging through the water after krill and fish, there are data confirming that humpback whales display bottom-feeding behaviors in areas of high concentrations of preferred prey, the northern sand lance (*Ammodytes dubius*) (Hain et al., 1995; Ware et al., 2014).

Baleen whales are believed to routinely encounter microplastics within the marine environment based on concentrations of these items and baleen whale feeding behaviors (Andrady, 2011). Observations of bowhead whale mouths have provided insights into potential threats to bowhead and right whales from oral entanglement of marine debris, including a greater probability of lethal consequences due to interference of the hydrostatic oral seal (Lambertsen et al., 2005). In a comprehensive review of documented ingestion of debris by marine mammals by Laist (1997), there are two species of mysticetes (bowhead and minke whale) with records of having ingested debris items that included plastic sheeting and a polythene bag. This effort was followed up by a comparative summary of the earlier review with additional information and the number of mysticete species with documented records of ingestion increased to seven species, including right whales, pygmy right whales, gray whales, and four rorqual species (Bergmann et al., 2015). Similarly, information compiled by (Williams et al., 2011) listed humpback whale, fin whale, minke whale as three species of mysticetes known to have ingested debris including items the authors characterized as fishing gear, polyethylene bag, plastic sheeting, plastic bags, rope, and general debris. Besseling et al. (2015) documented the first occurrence of microplastics in the intestines of a humpback whale. Anthropogenic debris have been found in the digestive tract of Southern right whales (Alzugaray et al., 2020), so it is probable that North Atlantic right whales also ingest marine debris.

Feeding behaviors of mysticete species suggest that potential encounters with ingestion stressors would only occur when debris items at the water's surface have spatial and temporal overlap with skim feeding animals, or while whales are engulfing prey in the water column as items sink to the bottom. Bottom-feeding humpback whales may also encounter ingestion stressors that have already sunk.

F.7.4.2 Odontocetes

In a comprehensive review of documented ingestion of debris by marine mammals, odontocetes had the most ingestion records, with 21 species represented (Laist, 1997). A follow-up to this review revealed an increase in odontocete ingestion of marine debris. Additionally, a follow-up to this review by Bergmann et al. (2015) revealed marine debris ingestion for odontocetes has increased, where 40 species now have documented records of ingestion.

Beaked whales use suction feeding to ingest benthic prey and may incidentally ingest other items (MacLeod et al., 2003). Both sperm whales and beaked whales are known to incidentally ingest foreign objects while foraging; however, this does not always result in negative consequences to health or vitality (Laist, 1997; Walker & Coe, 1990). While this incidental ingestion has led to sperm whale mortality in some cases, (Whitehead, 2003) suggested the scale to which this affects sperm whale populations was not substantial. Sperm whales are recorded as having ingested fishing net scraps, rope, wood, and plastic debris such as plastic bags and items from the seafloor (Jacobsen et al., 2010; Walker & Coe, 1990; Whitehead, 2003).

Weaned juveniles who are investigating multiple types of prey items may be particularly vulnerable to ingesting non-food items, as found in a study of juvenile harbor porpoises (Baird & Hooker, 2000). Similarly, a male pygmy sperm whale reportedly died from blockage of two stomach compartments by hard plastic, and a Blainville's beaked whale (*Mesoplodon densirostris*) washed ashore in Brazil with a ball of plastic thread in its stomach (Derraik, 2002). In one study, all 12 animals investigated from six odontocete species in the eastern Atlantic were found to have ingested microplastics, primarily fibers, and none larger than 5 mm (Montoto-Martínez et al., 2021).

F.7.4.3 Pinnipeds

Pinnipeds are opportunistic foragers, primarily feeding within the water column, but may also forage on the seafloor. Most of the seal species within the Study Area feed both within the water column and on the seafloor, while walruses feed primarily on benthic invertebrates (Bluhm & Grandinger, 2008). In a review of documented ingestion of debris by marine animals, 36 percent of seal species were found to have ingested plastics (Kuhn et al., 2015). Laist (1997) reported ingestion of Styrofoam cups by northern elephant seals and Steller sea lions, and (Bravo Rebolledo et al., 2013) reported plastics in the stomach contents of harbor seals. Plastic debris have been recorded in at least one hooded seal pup (Pinzone et al., 2021). The possibility of ingested debris transfer through predator-prey interactions has also been demonstrated by Eriksson and Burton (2003) in fur seals. As such, the risk of indirect ingestion of debris by marine mammals is dependent on the likelihood they are consuming contaminated prey.

F.7.4.4 Polar Bears

Polar bears feed primarily on other marine mammals (especially ringed seals, bearded seals, and harp seals) while on land and ice or out at sea (Bluhm & Grandinger, 2008). Plastics have also been found when assessing food items identified in scat samples (Iversen et al., 2013).

F.7.4.5 West Indian Manatee

Manatees feed on seagrass beds in relatively shallow coastal or estuarine waters. In a comprehensive review of documented ingestion of debris by marine mammals, the West Indian manatee had ingestion records that included monofilament line, plastic bags, string, twine, rope, fish hooks, wire, paper, cellophane, and rubber bands (Laist, 1997). Some researchers suggest that manatees incidentally ingest fishing gear and plastic while foraging on plants in shallow habitats where debris can accumulate and become entwined in the food resources (Adimey et al., 2014; Beck & Barros, 1991). Ingestion of fishing gear can cause impaction, abdominal infections, inversions of the intestine (Beck & Barros, 1991) and other indirect effects.

F.7.5 Secondary Stressors

This section analyzes potential effects on marine mammals exposed to stressors indirectly through effects on their habitat (sediment or water quality) or prey. For the purposes of this analysis, indirect effects on marine mammals via sediment or water quality that do not require trophic transfer (e.g., bioaccumulation) to be observed are considered here. The invertebrates (Section 3.4), marine habitats (Section 3.5), and fish (Section 3.6) analyses indicated minimal to no effects on potential prey species of marine mammals due to bioaccumulation. It is important to note that the terms “indirect” and “secondary” do not imply reduced severity of environmental consequences but instead describe how the effect may occur in an organism. Bioaccumulation is considered in the *Ecosystem Technical Report for the Atlantic Fleet Training and Testing (AFTT) Final Environmental Impact Statement* (U.S. Department of the Navy, 2012b).

Stressors from Navy military readiness activities that could pose indirect effects on marine mammals via habitat or prey include: (1) explosives, (2) explosive byproducts and unexploded munitions, (3) metals, (4) chemicals, and (5) transmission of disease and parasites. Analyses of the potential effects on sediment and water quality are discussed in Section 3.2 (Sediment and Water Quality).

F.7.5.1 Explosives

Explosives may have an effect on marine mammal prey species. In addition to the physical effects of an underwater blast, prey might have behavioral reactions to underwater sound. For instance, prey species might exhibit a strong startle reaction to explosions that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals (Hanlon & Messenger, 1996; Mather, 2004). The abundances of prey species near the detonation point could be diminished for a short period of time before being repopulated by animals from adjacent waters. Alternatively, any prey species that would be directly injured or killed by the blast could draw in scavengers from the surrounding waters that would feed on those organisms, and in turn could be susceptible to becoming directly injured or killed by subsequent explosions. Any of these scenarios would be temporary, only occurring during activities involving explosives, and no lasting effect on prey availability or the pelagic food web would be expected.

F.7.5.2 Explosion Byproducts and Unexploded Munitions

A series of research efforts that focused on World War II underwater munitions disposal sites in Hawaii (Briggs et al., 2016; Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information regarding the effects of undetonated materials and unexploded munitions on marine species. Section 3.2.3.1 (Explosives and Explosives Byproducts) and Section 3.2.3.2 (Metals) contain a summary of this literature which investigated water and sediment quality effects, on a localized scale, from munitions ocean disposal sites and ocean disposed dredge spoils sites. Findings from these studies indicate that there were no adverse effects on the local ecology from the presence of degrading munitions and there was no bioaccumulation of munitions-related chemicals in local marine species.

The island of Farallon De Medinilla (in the Mariana Islands) has been used as a target area since 1971. Between 1997 and 2012, there were 14 underwater scientific survey investigations around the island providing a long-term insight to the potential effects on the marine life from training and testing involving the use of munitions (Smith & Marx, 2016). Munitions use has included high-explosive rounds from gunfire, high-explosives bombs by Navy aircraft and U.S. Air Force B-52s, in addition to the expenditure of inert rounds and non-explosive practice bombs. Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, and bony fishes, and sea turtles. Over the 16-year period, investigators found no evidence that the condition of biological resources has been adversely affected to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals, and other marine resources were comparable, or superior to, those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as the Potomac River Test Range at Dahlgren, Virginia, which was established in 1918 and is the nation’s largest fully instrumented, over-the-water gun-firing range. Munitions tested at Naval Surface Warfare Center, Dahlgren have included rounds from small-caliber guns up to the Navy’s largest (16-in. guns), bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013e). Results from the assessment indicate that munitions expended at Naval Surface Warfare Center, Dahlgren have not contributed to significant concentrations of metals in the Potomac River. Sediment contribution of metals is orders of magnitude less than concentrations already present in the Potomac River from natural and manmade sources (U.S. Department of the Navy, 2013e).

F.7.5.3 Metals

Metals are introduced into seawater and sediments as a result of military readiness activities involving ship hulks, targets, munitions, and other military expended materials (Section 3.2.3.2, Metals) (Environmental Sciences Group, 2005a). Some metals bioaccumulate and physiological effects begin to occur only after several trophic transfers concentrate the toxic metals (Section 3.5, Habitats, and Chapter 4, Cumulative Effects). Evidence from a number of studies (Briggs et al., 2016; Kelley et al., 2016; Koide et al., 2016; U.S. Department of the Navy, 2013e; University of Hawaii, 2010) indicate metal contamination is very localized and that bioaccumulation resulting from munitions cannot be demonstrated. Specifically in sampled marine life living on or around munitions on the seafloor, metal concentrations could not be definitively linked to the munitions since comparison of metals in sediment next to munitions show relatively little difference in comparison to other “clean” marine sediments used as a control/reference (Koide et al., 2016). Research has demonstrated that some smaller marine organisms are attracted to metal munitions as a hard substrate for colonization or as shelter (Kelley et al., 2016; Smith & Marx, 2016), but this is unlikely to substantively affect marine mammal prey availability.

F.7.5.4 Chemicals

Several Navy military readiness activities introduce chemicals into the marine environment that are potentially harmful at higher concentrations; however, rapid dilution would occur, and toxic concentrations are unlikely to be encountered. Introduced chemicals are principally from flares and propellants from missiles and torpedoes. Properly functioning flares, missiles, and torpedoes combust most of their propellants, leaving benign, or readily diluted soluble combustion byproducts (e.g., hydrogen cyanide). Operational failures may allow propellants and their degradation products to be released into the marine environment. Flares and missiles that operationally fail may release perchlorate, which is highly soluble in water, persistent, and affect s metabolic processes in many plants and animals if in sufficient concentration. Such concentrations are not likely to persist in the ocean. Research has demonstrated that perchlorate did not bioconcentrate or bioaccumulate, which was consistent with the expectations for a water-soluble compound (Furin et al., 2013). Perchlorate from failed expendable items is therefore unlikely to compromise water quality to that point that it would act as a secondary stressor to marine mammals. It should also be noted that chemicals in the marine environment as a result of Navy military readiness activities would not occur in isolation and are typically associated with military expended materials that release the chemicals while in operation. Because marine mammal avoidance of an expended flare, missile, or torpedo in the water is almost certain, it would further reduce the potential for introduced chemicals to act as a secondary stressor.

F.7.5.5 Transmission of Marine Mammal Diseases and Parasites

The U.S. Navy deploys trained common bottlenose dolphins (*Tursiops truncatus*) and California sea lions (*Zalophus californianus*) for integrated training involving two primary mission areas: to find objects such as inert mine shapes, and to detect swimmers or other intruders around Navy facilities such as piers. When deployed, the animals are part of what the Navy refers to as Marine Mammal Systems. These Marine Mammal Systems include one or more motorized small boats, several crew members, and a trained marine mammal. Based on the standard procedures with which these systems are deployed, it is not reasonably foreseeable that use of these Marine Mammals Systems would result in the transmission of disease or parasites to cetaceans or pinnipeds in the Study Area based on the following.

Each trained animal is deployed under behavioral control to find the intruding swimmer or submerged object. Upon finding the target of the search, the animal returns to the boat and alerts the animal handlers that an object or swimmer has been detected. In the case of a detected object, the human handlers give the animal a marker that the animal can bite onto and carry down to place near the detected object. In the case of a detected swimmer, animals are given a localization marker or leg cuff that they are trained to deploy via a pressure trigger. After deploying the localization marker or leg cuff, the animal swims free of the area to return to the animal support boat. For detected objects, human divers or remote vehicles are deployed to recover the item. Swimmers that have been marked with a leg cuff are reeled in by security support boat personnel via a line attached to the cuff.

Marine Mammal Systems deploy approximately one to two weeks before the beginning of a training exercise to allow the animals to acclimate to the local environment. Four to 12 marine mammals are involved per exercise. Marine Mammal Systems typically participate in object detection and recovery, both participating in mine warfare exercises and assisting with the recovery of non-explosive mine shapes at the conclusion of an exercise. Marine Mammal Systems may also participate in port security and anti-terrorism/force protection exercises.

During the past 40 years, the Navy Marine Mammal Program has been deployed globally. To date, there have been no known instances of deployment-associated disease transfer to or from Navy marine mammals. Navy animals are maintained under the control of animal handlers and are prevented from having sustained contact with indigenous animals.

When not engaged in the training event, Navy marine mammals are either housed in temporary enclosures or aboard ships involved in training exercises. All marine mammal waste is disposed of in a manner approved for the specific holding facilities. When working, sea lions are transported in boats, and dolphins are transferred in boats or by swimming alongside the boat under the handler’s control. Their open-ocean time is under stimulus control and is monitored by their trainers.

Navy marine mammals receive excellent veterinarian care (per Secretary of the Navy Instruction 3900.41E). Appendix A, Section 8, of the Swimmer Interdiction Security System Final EIS (U.S. Department of the Navy, 2009b) presents an overview of the veterinary care provided for the Navy’s marine mammals. Appendix B (Activity Stressor Matrices), Section 2, of the Swimmer Interdiction Security System Final EIS presents detailed information on the health screening process for communicable diseases. The following is a brief summary of the care received by all of the Navy’s marine mammals:

- Qualified veterinarians conduct routine and pre-deployment health examinations on the Navy’s marine mammals; only animals determined as healthy are allowed to deploy.
- Restaurant-quality frozen fish are fed to prevent diseases that can be caused by ingesting fresh fish (e.g., parasitic diseases).
- Navy animals are routinely dewormed to prevent parasitic and protozoal diseases.
- If a valid and reliable screening test is available for a regionally relevant pathogen (e.g., polymerase chain reaction assays for morbillivirus), such tests are run on appropriate animal samples to ensure that animals are not shedding these pathogens.

The Navy Marine Mammal Program routinely does the following to further mitigate the low risk of disease transmission from captive to wild marine mammals during training exercises:

- Marine mammal waste is disposed of in an approved system dependent upon the animal’s specific housing enclosure and location.
- Onsite personnel are made aware of the potential for disease transfer and report any sightings of wild marine mammals so that all personnel are alert to the presence of the animal.
- Marine mammal handlers visually scan for indigenous marine animals for at least five minutes before animals are deployed and maintain a vigilant watch while the animal is working in the water. If a wild marine mammal is seen approaching or within 100 m, the animal handler will

hold the marine mammal in the boat or recall the animal immediately if the animal has already been sent on the mission.

- The Navy obtains appropriate state agriculture and other necessary permits and strictly adheres to the conditions of the permit.

Due to the limited amount of time that the Navy marine mammals spend in the open ocean, the control that the trainers have over the animals, the collection and proper disposal of marine mammal waste, the exceptional screening and veterinarian care given to the Navy's animals, the visual monitoring for indigenous marine mammals, and more than 40 years with zero known incidents, there is no scientific basis to conclude that the use of Navy marine mammals during training activities will have an effect on wild marine mammals.

F.8 Reptiles

F.8.1 Energy Stressors

F.8.1.1 Effects from High-Energy Lasers

As discussed in Section 3.0.3.3.3.3 (High-Energy Lasers), high-energy laser weapons testing involves the use of up to 30 kilowatts of directed energy as a weapon against small surface vessels and airborne targets. These weapons systems are deployed from a surface ship to create small but critical failures in potential targets and used at short ranges from the target.

This section analyzes the potential effects of high-energy lasers on sea turtles. Sea snakes were not included in the model—it is generally assumed that sea snake occurrence within the Study Area is very rare. Because of the low density of sea snakes in open ocean areas where high-energy laser testing would occur, sea snakes are assumed to not be affected by high-energy laser strikes due to the extremely low likelihood of exposure. Therefore, sea snakes are not discussed further in the analysis for potential effects on reptiles by testing activities using high-energy lasers.

The primary concern for high-energy weapons testing is the potential for a sea turtle to be struck by a high-energy laser beam at or near the water's surface, which could result in injury or death, resulting from traumatic burns from the beam.

Sea turtles could be exposed to a laser only if the beam missed the target. Should the laser strike the sea surface, individual sea turtles at or near the surface could be exposed. The potential for exposure to a high-energy laser beam decreases as the water depth increases. Because laser platforms are typically helicopters and ships, sea turtles at sea would likely transit away or submerge in response to other stressors, such as ship or aircraft noise, although some sea turtles may not exhibit a response to an oncoming vessel or aircraft, increasing the risk of contact with the laser beam.

As discussed in Section 3.0.3.3.3.3 (High-Energy Lasers), high-energy laser use associated with training and testing activities would occur within the Hawaii Study Area and California Study Area. Training and testing activities have the potential to expose sea turtles that occur within these areas to this energy stressor.

Appendix I (Military Expended Materials and Direct Strike Impact Analyses) includes a conservative approach for estimating the probability of a direct laser strike on a sea turtle during testing and training activities. The Navy analysis assumes: (1) that all sea turtles would be at or near the surface 100 percent of the time, and would not account for the duration of time a sea turtle would be diving; and (2) that sea turtles are stationary, which does not account for any movement or any potential avoidance of the training or testing activity in response to other stressors (e.g., vessel noise).

The Navy compiled density data from several sources and developed a protocol to select the best available data sources based on species, area, time (season), and type of density model. The resulting GIS database, called the Navy Marine Species Density Database (U.S. Department of the Navy, 2017b), includes seasonal density values for sea turtle species present within the Study Area. When aerial surveys are used to collect data on sea turtle occurrence it is often difficult to distinguish between the different sea turtle species. To account for the known occurrence of multiple sea turtle species in the Study Area and the general lack of species-specific occurrence data for most species, a sea turtle guild, composed of green and hawksbill turtle sightings, was created to estimate sea turtle densities in the Hawaii Study Area. The sea turtle guild was not used to estimate sea turtle densities in the transit corridor (eastern or western portions) or for the California Study Area due to the scarcity of sea turtle sightings data in these areas.

While the analysis of sea turtle guild survey data applies to all species, it is more reflective of green turtles, which account for nearly all sightings in the Hawaii Study Area. The number of observations of hawksbill turtles would be so low as to render the data unusable for estimating density of this species. By considering the hawksbill and green turtle sightings together, a more powerful result can be provided for sea turtles as a guild. In theory, the guild also encompasses leatherback, olive ridley, and loggerhead turtles, but these species have not been identified during the collection of Navy monitoring data. The Navy's modeling results show a probability of 0.000064 strikes per year on a sea turtle. Based on the assumptions used in the statistical probability analysis, there is a high level of certainty in the conclusion that no sea turtle that occurs in the Study Area would be struck by a high-energy laser.

F.8.2 Physical Disturbance and Strike Stressors

F.8.2.1 Effects from Vessels and In-Water Devices

Vessels

Sea turtles spend a majority of their time submerged (Renaud & Carpenter, 1994; Sasso & Witzell, 2006), though Hazel et al. (2009) and Hazel et al. (2007) showed most species of sea turtles staying within the top 3 m of water despite deeper water being available. Any of the sea turtle species found in the Study Area can occur at or near the surface in open ocean and coastal areas, whether feeding or periodically surfacing to breathe. Distribution of species is not uniform, however. Typically in Hawaii, loggerheads and olive ridleys are not seen in nearshore habitats because they are either transiting (relatively briefly occurring within nearshore waters) or are in more pelagic habitats. Similarly for San Diego Bay, green sea turtles are regularly seen within the bay, but not other species. Green sea turtles are the most abundant sea turtles found in the nearshore environment of the Study Area, and in Hawaii, are observed to bask on land. Loggerheads, considered to be the most generalist of sea turtle species in terms of feeding and foraging behavior, apparently exhibit varied dive behavior that is linked to the quantity and quality of available resources. Foley et al. (2011) found that loggerheads spent 7.3 percent of time at the surface (associated with breathing), 42 percent of time under the surface but close to the surface within one body length, and 44 percent of time within the water column (the remaining time observed at or near the seafloor). Leatherback sea turtles are more likely to feed at or near the surface in open ocean areas. It is important to note that leatherbacks can forage for jellyfish at depth but bring them to the surface to ingest (Benson et al., 2007; Fossette et al., 2007; James & Herman, 2001). Basking on the water's surface is common for all species within the Study Area as a strategy to thermoregulate, and the reduced activity associated with basking may pose higher risks for sea turtle strikes because of a likely reduced capacity to avoid cues. Green, hawksbill, and loggerhead sea turtles are more likely to forage nearshore, and although they may feed along the seafloor, they surface periodically to breathe while feeding and moving between nearshore habitats.

In an attempt to determine traffic patterns for Navy and non-Navy vessels, the Center for Naval Analysis (Mintz, 2012; Mintz & Parker, 2006) conducted a review of historic data for commercial vessels, coastal shipping patterns, and Navy vessels. Within the Hawaii portion of the HCTT Study Area, significant commercial traffic is present as vessels bring shipments of goods to Hawaii as well as shipments between the islands. Trans-Pacific vessel traffic that passes through offshore waters near Hawaii are associated with transits between Asian ports and ports along the U.S. west coast or the Panama Canal. Commercial and non-Navy traffic, which included cargo vessels, bulk carriers, passenger vessels, and oil tankers (all over 20 m in length), was heaviest along the U.S. West Coast between San Diego and Seattle (Puget Sound) and between the Hawaiian Islands and the Panama Canal (Mintz & Parker, 2006). Well-defined International shipping lanes within the Study Area are also heavily traveled. Compared to coastal vessel activity, there was relatively little concentration of vessels in the other portions of the Study Area (Mintz & Parker, 2006). Vessel traffic data from 2009 shows that Navy vessels accounted for less than 10 percent of the total large vessel traffic (from estimated vessel hours) in the Study Area (Mintz, 2012). In the California Study Area where Navy vessel activity is concentrated within the exclusive economic zone, the Navy vessels accounted for 24 percent of the total large vessel traffic (Mintz, 2012).

A total of 298 sea turtle strandings were reported in the Hawaiian Islands, from all causes between 1982 and 2007. Based on an observed annual average of eight green sea turtles stranded in the Main Hawaiian Islands between 1982 and 2007, and after applying a correction factor for those that do not strand, NMFS estimated 25–50 green sea turtles are killed by vessel strike annually in the Main Hawaiian Islands (National Marine Fisheries Service, 2008a). A total of two hawksbill sea turtles were observed stranded with obvious boat strike injuries in the Main Hawaiian Islands between 1982 and 2008. The majority of strandings are likely the result of strikes with relatively small, but high speed fishing boats making thousands of trips through Hawaiian nearshore waters annually. As a term and condition for NMFS's Reinitiated Biological Opinion, the Navy prepared an analysis of all sea turtle strandings within the Hawaii Study Area (National Marine Fisheries Service, 2015). The reinitiated consultation included additional sea turtle information, in waters within Pearl Harbor and near the Pearl Harbor entrance, as well as waters surrounding Oahu in order to improve the understanding of sea turtle strikes. The vast majority of the strandings were green sea turtles (96 percent) with the remaining reported as hawksbill sea turtles or unidentifiable sea turtles. Most of these strandings were from Oahu (approximately 70 percent). Of all reported strandings, 7 percent were attributed to vessel strike, with most (34 percent) from unspecified causes and 27 percent from fisheries interactions. The remainder were attributed to disease, predation, entrapment, and natural mortality (National Marine Fisheries Service, 2015).

The frequency of vessel strike in open ocean waters surrounding Hawaii is much less clear. It is assumed if an animal is struck in waters further from shore, it is less likely to strand and be documented. There has been one recent report of a stranded turtle in Hawaii that appeared as though it may have been struck by a large propeller (such as those used by some Navy vessels) (National Marine Fisheries Service, 2008a). However, it is more likely turtles struck by large propellers would not strand because the damage to the carcass would be so extensive as to facilitate sinking or consumption by scavengers.

There is not a high level of sea turtle stranding data on the U.S. West Coast (National Marine Fisheries Service, 2008a). This does not necessarily indicate vessel strike is less common off the U.S. West Coast versus Hawaii. Ocean currents, vessel sizes, or other factors may simply affect the likelihood a struck turtle will strand. Regardless, this lack of stranding data makes estimating the frequency of sea turtle vessel strike off the U.S. West Coast difficult. Most observations of stranded sea turtles in Southern California since 1990 occurred within San Diego Bay, where a population of green sea turtles resides. Between 1990 and 2014, 10 green sea turtle strandings were observed with evidence of boat collision (National Marine Fisheries Service, 2008a). No other sea turtle species have stranded near or in the California Study Area that have had evidence of boat strike (National Marine Fisheries Service, 2008a). As a term and condition for NMFS's Reinitiated Biological Opinion, the Navy prepared an analysis of all sea turtle strandings within Southern California for 2015. Only seven strandings of sea turtles were reported in 2015. Four of these strandings were green sea turtles, two were loggerheads, and one was olive ridley. Only three sea turtles were reported as struck by vessels, all of whom were green sea turtles. These strandings were reported within San Diego Bay and were located in areas that are not used by the Navy (National Marine Fisheries Service, 2015).

Disturbance of sea turtles from vessel movements is expected to occur with more frequency than actual strikes. Visual cues from vessels nearby and vessel noise would likely induce short-term behavioral changes, such as cessation of foraging activities or moving away from the disturbance.

In-Water Devices

In-water devices are generally smaller (several inches to 111 ft.) than most Navy vessels. For a discussion on the types of activities that use in-water devices see Appendix B (Activity Stressor Matrices), and for information on where in-water devices are used, and how many exercises would occur under each alternative, see Section 3.0.3.3.4.1 (Vessels and In-Water Devices).

Devices that could pose a collision risk to sea turtles are those operated at high speeds and are unmanned. The Navy reviewed torpedo design features and a large number of previous anti-submarine warfare torpedo exercises to assess the potential of torpedo strikes on marine mammals, and its conclusions are also relevant to sea turtles. The acoustic homing programs of Navy torpedoes are sophisticated and would not confuse the acoustic signature of a marine mammal with a submarine/target. It is reasonable to assume that acoustic signatures of sea turtles would also not be confused with a submarine or target. All exercise torpedoes are recovered and refurbished for eventual re-use. Review of the exercise torpedo records indicates there has never been an effect on a sea turtle. In thousands of exercises in which torpedoes were fired or in-water devices used, there have been no recorded or reported instances of a marine species strike from a torpedo or any other in-water device.

Since some in-water devices are identical to support craft, (typically less than 15 m in length), sea turtles could respond to the physical presence of the device similar to how they respond to the physical presence of a vessel (see Table 3.0-17). Physical disturbance from the use of in-water devices is not expected to result in more than a momentary behavioral response. These responses would likely include avoidance behaviors (swimming away or diving) and cessation of normal activities (e.g., foraging). As with an approaching vessel, not all sea turtles would exhibit avoidance behaviors and be at higher risk of a strike.

In-water devices, such as unmanned underwater vehicles, that move slowly through the water are highly unlikely to strike sea turtles because the turtle could easily avoid the object. Towed devices are unlikely to strike a sea turtle because of the observers on the towing platform and other standard safety measures employed when towing in-water devices. Sea turtles that occur in areas that overlap with in-water device use within the Study Area may encounter in-water devices. It is possible that sea turtles may be disturbed by the presence of these activities, but any disturbance from the use of in-water devices is not expected to result in more than a temporary behavioral response.

Propulsion testing events occur infrequently but pose a higher strike risk because of the higher speeds at which the vessels need to achieve in order to complete the testing activity. These activities could occur in the Hawaii Study Area and California Study Area. However, there are just a few of these events proposed per year, so the increased risk is nominal compared to all vessel use proposed under Alternative 1.

As discussed in Section 3.0.3.3.4.1 (Vessels and In-Water Devices), testing activities involving the use of in-water devices would occur in the HCTT Study Area at any time of year. Unmanned surface vehicle use would occur within both the Hawaii Study Area and California Study Area.

As with training activities, the likelihood is low for testing activities to cause harmful interaction with a vessel or in-water device but cannot be wholly discounted. Sea turtle strikes in high vessel traffic areas (e.g., Pearl Harbor) have been reported. Potential effects of exposure to vessels may result in substantial changes in an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. Any strike at high speed is likely to result in significant injury. Potential effects of exposure to vessels are not expected to result in population-level effects for all sea turtle species. Under Alternative 1 testing activities, the Navy will continue to implement visual observation mitigation to avoid or reduce the potential for vessel and in-water device strike of sea turtles. Within a mitigation zone of a vessel or in-water device, trained observers will relay sea turtle locations to the operators, who are required to change course (no course change would be implemented if the vessel's safety is threatened, the vessel is restricted in its ability to maneuver [e.g., during launching and recovery of aircraft or landing craft, during towing activities, when mooring, etc.], or if the vessel is operated autonomously). A mitigation zone size is not specified for sea turtles to allow flexibility based on vessel type and mission requirements (e.g., small boats operating in a narrow harbor).

F.8.2.2 Effects from Military Expended Materials

The primary concern is the potential for a sea turtle to be struck with a military expended material at or near the water's surface, which could result in injury or death. For sea turtles, although disturbance or strike from an item as it falls through the water column is possible, it is not likely because the objects generally sink through the water slowly and can be avoided by most sea turtles. Materials will slow in their velocity as they approach the bottom of the water and will likely be avoided by any juvenile or adult sea turtles (e.g., olive ridley, green, loggerhead, or hawksbill turtles) that happen to be in the vicinity foraging in benthic habitats. Therefore, the discussion of military expended materials strikes focuses on the potential of a strike at the surface of the water.

There is a possibility that an individual turtle at or near the surface may be struck if they are in the target area at the point of physical impact at the time of non-explosive munitions delivery. Expended munitions may strike the water surface with sufficient force to cause injury or mortality. Adult sea turtles are generally at the surface for short periods, and spend most of their time submerged; however, hatchlings and juveniles spend more time at the surface while in ocean currents or at the surface while basking. The leatherback sea turtle is more likely to be foraging at or near the surface in the open ocean than other species, but the likelihood of being struck by a projectile remains very low because of the wide spatial distribution of leatherbacks relative to the point location of an activity. Furthermore, projectiles are aimed at targets, which will absorb the impact of the projectile.

While no strike from military expended materials has ever been reported or recorded on a reptile, the possibility of a strike still exists. Therefore, the potential for sea turtles to be struck by military expended materials was evaluated using statistical probability modeling to estimate potential direct strike exposures to a sea turtle. To estimate potential direct strike exposures, a worst-case scenario was calculated using the sea turtle with the highest average year-round density in areas with the highest military expended material expenditures in the Hawaii and California portions of the HCTT Study Area (see Appendix I, Military Expended Materials and Direct Strike Impact Analyses). The green sea turtle was used as a proxy for all sea turtle species because this species has the highest density estimates, which would provide the most conservative modeling output results. For estimates of expended materials in all areas, see Section 3.0.3.3.4.2 (Military Expended Materials). Input values include munitions data (frequency, footprint and type), size of the training or testing area, sea turtle density data, and size of the animal. To estimate the potential of military expended materials to strike a sea turtle, the impact area of all military expended materials was totaled over one year in the area with the highest combined amounts of military expended materials for the Proposed Action. The analysis of the potential for a sea turtle strike is influenced by the following assumptions:

- The model is two-dimensional, assumes that all sea turtles would be at or near the surface 100 percent of the time, and does not consider any time a sea turtle would be submerged.
- The model also does not take into account the fact that most of the projectiles fired during training and testing activities are fired at targets, and that most projectiles hit those targets, so only a very small portion of those would hit the water with their maximum velocity and force.
- The model assumes the animal is stationary and does not account for any movement of the sea turtle or any potential avoidance of the training or testing activity.

The potential of fragments from high-explosive munitions or expended material other than munitions to strike a sea turtle is likely lower than for the worst-case scenario calculated above because those events happen with much lower frequency. Fragments may include metallic fragments from the exploded target, as well as from the exploded munitions.

There is a possibility that an individual turtle at or near the surface may be struck if they are in the target area at the point of physical impact at the time of non-explosive munitions delivery. Expended munitions may strike the water surface with sufficient force to cause injury or mortality. Direct munitions strikes from non-explosive bombs, missiles, and rockets are potential stressors to some species. Some individuals at or near the surface may be struck directly if they are at the point of impact at the time of non-explosive practice munitions delivery. However, most missiles hit their target or are disabled before hitting the water. Thus, most of these missiles and aerial targets hit the water as fragments, which quickly dissipates their kinetic energy within a short distance of the surface.

Adult sea turtles are generally at the surface for short periods and spend most of their time submerged; however, hatchlings and juveniles of all sea turtle species spend more time at the surface while in ocean currents, and all sea turtle life stages bask on the surface. Leatherback sea turtles of all age classes are more likely to be foraging at or near the surface in the open ocean than other species, but the likelihood of being struck by a projectile remains very low because of the wide spatial distribution of leatherbacks relative to the point location of an activity. Furthermore, projectiles are aimed at targets, which will absorb the impact of the projectile. Other factors that further reduce the likelihood of a sea turtle being struck by an expended munition include the recovery of all non-explosive torpedoes as well as target-related materials that are intact after the activity. The Navy will implement mitigation (e.g., not conducting gunnery activities against a surface target when a specified distance from sea turtles) to avoid potential effects from military expended materials on sea turtles throughout the Study Area (see Section 5.6, Activity-based Mitigation).

F.8.2.3 Effects from Seafloor Devices

The types of activities that use seafloor devices include items placed on, dropped on, or that move along the seafloor such as mine shapes, anchor blocks, anchors, bottom-placed instruments, and bottom-crawling unmanned underwater vehicles. The likelihood of any sea turtle species encountering seafloor devices is considered low because these items are either stationary or move very slowly along the bottom. A benthic-foraging sea turtle would likely avoid the seafloor device. In the unlikely event that a sea turtle is in the vicinity of a seafloor device, the slow movement and stationary characteristics of these devices would not be expected to physically disturb or alter natural behaviors of sea turtles. Moreover, objects falling through the water column will slow in velocity as they sink toward the bottom and could be avoided by most sea turtles. Therefore, these items do not pose a significant strike risk to sea turtles. The only seafloor device used during military readiness activities that has the potential to strike a sea turtle at or near the surface is an aircraft deployed mine shape, which is used during aerial mine laying activities. These devices are identical to non-explosive practice bombs discussed above in Section F.8.2.2 (Effects from Military Expended Materials).

Based on the analysis, there is a reasonable level of certainty that no sea turtles would be struck by seafloor devices. The likelihood of a sea turtle encountering seafloor devices in benthic foraging habitats is considered low because these items are either stationary or move very slowly along the bottom. Seafloor devices are not likely to interfere with sea turtles resident to, or engaging in migratory, reproductive, and feeding behaviors within the range complexes of the Study Area. Further, seafloor devices would only affect sea turtle species that are foraging in benthic habitats (e.g., olive ridley, loggerhead, and green sea turtles). Sea turtles in coastal habitats can occur near the bottom when foraging or resting. Sea turtles encountering seafloor devices are likely to avoid them. Given the slow movement of seafloor devices, the effort expended by sea turtles to avoid them will be minimal, temporary, and not have fitness consequences.

F.8.3 Entanglement Stressors

F.8.3.1 Effects from Wires and Cables

Fiber optic cables are flexible cables that can range in size up to 3,000 m in length. Longer cables present a higher likelihood of sea turtle interactions, and therefore present an increased risk of entanglement of a sea turtle. Other factors that increase risk of sea turtle interactions with fiber optic cables include the amount of time a fiber optic cable is in the same vicinity of a sea turtle; however, these cables will only be within the water column during the activity and while they sink, the likelihood of a sea turtle encountering and becoming entangled within the water column is extremely low. Fiber optic cables exhibit several physical qualities that reduce the risk of entanglement. Primarily, these cables are brittle and break easily. Because of the physical properties of fiber optic material, the cable is brittle and easily broken when kinked, twisted, or bent sharply. The cables are often designed with controlled buoyancy to minimize the cable's effect on vehicle movement. The fiber optic cable would be suspended within the water column during the activity, and then be expected to sink to the seafloor. Further, activities that use fiber optic cables occur in deep waters. These factors reduce the likelihood that a fiber optic cable would be in close proximity to a sea turtle—the cable is only buoyant during the training and testing activity, and subsequently sinks after use to rest in benthic habitats. If the isobaths is greater than the maximum benthic foraging ability (dive depth) of a sea turtle, then these cables would not present an entanglement risk. For example, as discussed previously, leatherbacks may dive to depths greater than 1,000 m in search of prey (e.g., jellyfish), while other species (e.g., loggerheads) may forage in benthic habitats as deep as approximately 200 m, and juvenile sea turtles (e.g., green sea turtles) resting and foraging in waters as deep as approximately 30 (Hochscheid, 2014; Rieth et al., 2011). In addition, because of the physical properties of the fiber optic material, the cable is unlikely to entangle a sea turtle body or appendage because the cable would likely break before an entangling loop would form. If a loop did form around an appendage or sea turtle body, the cable would subsequently break quickly on its own or in response to sea turtle movement. Therefore, fiber optic cables present an entanglement risk to sea turtles, but it is unlikely that an entanglement event would occur and any entanglement would be temporary (a few seconds) before the sea turtle could resume normal activities. As noted in Section H.6.1.3 (General Threats), entanglement by fishing gear is a serious global threat to sea turtles. The various types of marine debris attributed to sea turtle entanglement (e.g., commercial fishing gear, towed gear, stationary gear, or gillnets) have substantially higher (up to 500–2,000 lb.) breaking strengths at their "weak links." If fiber optic cables and fragments of cables sink to the seafloor in an area where the bottom is calm, they would remain there undisturbed. In an area with bottom currents or active tidal influence, the fiber optic strands may move along the seafloor, away from the location in which they were expended and potentially into sea turtle benthic foraging habitats. Over time, these strands may become covered by sediment in most areas or colonized by attaching and encrusting organisms, which would further stabilize the material and reduce the potential for reintroduction as an entanglement risk.

Similar to fiber optic cables discussed above, guidance wires may pose an entanglement threat to sea turtles either in the water column or after the wire has settled to the seafloor. The Navy previously analyzed the potential for entanglement of sea turtles by guidance wires and concluded that the potential for entanglement is low (U.S. Department of the Navy, 1996). These conclusions have also been carried forward in NMFS analyses of Navy training and testing activities (National Marine Fisheries Service, 2013). The likelihood of a sea turtle encountering and becoming entangled in a guidance wire depends on several factors. With the exception of a chance encounter with the guidance wire while it is sinking to the seafloor (at an estimated rate of 0.7 ft. per second), it is most likely that a sea turtle would only encounter a guidance wire once it had settled on the seafloor. Since the guidance wire will only be within the water column during the activity and while it sinks, the likelihood of a sea turtle encountering and becoming entangled within the water column is extremely low. Guidance wires have a relatively low tensile breaking strength; between 10 and 42 lb. and can be broken by hand (National Marine Fisheries Service, 2008a). In addition, based on degradation times, the guidance wires would break down within one to two years and therefore no longer pose an entanglement risk. As with fiber optic cables, guidance wire fragments may move with bottom currents or active tidal influence, and present an enduring entanglement risk if the wires were moved into benthic foraging habitats. Subsequent colonization by encrusting organisms, burying by sediment, and chemical breakdown of the copper filament would further reduce the potential for reintroduction as an entanglement risk. The length of the guidance wires varies, as described in Section 3.0.3.3.5.1 (Wires, Cables, and Nets), but greater lengths increase the likelihood that a sea turtle could become entangled. The behavior and feeding strategy of a species can determine whether it may encounter items on the seafloor, where guidance wires will most likely be available. There is potential for those species that feed on the seafloor to encounter guidance wires and potentially become entangled; however, the relatively few guidance wires being expended within the HCTT Study Area limits the potential for encounters.

Sonobuoys consist of a surface antenna and float unit and a subsurface hydrophone assembly unit. The two units are attached through a thin-gauge, dual-conductor, hard draw copper strand wire, which is then wrapped by a hollow rubber tubing or bungee in a spiral configuration. The tensile breaking strength of the sonobuoy wire and rubber tubing is no more than 40 lb. The length of the sonobuoy wire is housed in a plastic canister dispenser, which remains attached upon deployment. The length of cable that extends out is no more than 1,500 ft. and is dependent on the water depth and type of sonobuoy. Attached to the sonobuoy wire is a kite-drogue and damper disk stabilizing system made of non-woven nylon fabric. The nylon fabric is very thin and can be broken by hand. The sonobuoy wire runs through the stabilizing system and leads to the hydrophone components. The hydrophone components may be covered by thin plastic netting depending on type of sonobuoy. Each sonobuoy has a saltwater activated polyurethane float that inflates when the sonobuoy is submerged and keeps the sonobuoy components floating vertically in the water column below it. Sonobuoys remain suspended in the water column for no more than 30 hours, after which they sink to the seafloor. Several factors reduce the likelihood of sea turtle entanglement from sonobuoy components. The materials that present an entanglement risk in sonobuoys are weak, and if wrapped around an adult or juvenile sea turtle, would likely break soon after entanglement or break while bending into potentially entangling loops, although hatchlings would not likely be able to escape entrapment if entangled. These materials, however, are only temporarily buoyant and would begin sinking after use in an activity. The entanglement risk from these components would only occur when a sea turtle and these components were in close proximity, which is only in the water column. These materials would be expended in waters too deep for benthic foraging, so bottom foraging sea turtles would not interact with these materials once they sink. Some sonobuoy components, once they sink to the bottom, may be transported by bottom currents or active tidal influence, and present an enduring entanglement risk. In the benthic environment, subsequent colonization by encrusting organisms, burying by sediment, and chemical breakdown of the various materials would further reduce the potential for reintroduction as an entanglement risk.

Training activities under Alternative 1 would expend wires and cables throughout the Study Area.

Based on the numbers and geographic locations of their use, wires and cables used during training activities are analyzed for their potential to entangle sea turtles. Any species of sea turtle that occurs in the Study Area could at some time encounter expended cables or wires. The sink rates of cables and wires would rule out the possibility of these drifting great distances into nearshore and coastal areas where green, hawksbill, olive ridley, and loggerhead sea turtles are more likely to occur and feed on the bottom. The leatherback is more likely to co-occur with these activities, given its preference for open-ocean habitats, but this species is known to forage on jellyfish at or near the surface. Hatchlings and juveniles of some sea turtle species (e.g. greens and loggerheads), may occur in open-ocean habitats, too. Under Alternative 1, exposure to cables and wires used in training activities may cause short-term or long-term disturbance to an individual turtle because if a sea turtle were to become entangled in a cable or wire, it could free itself, or the entanglement could lead to injury or death. Potential effects of exposure to cable or wire may result in changes to an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. However, wires and cables are generally not expected to cause disturbance to sea turtles because (1) sea turtles would only be exposed to potential entanglement risk as the wire or cable sinks through the water column; (2) due to their behavior, sea turtles are unlikely to become entangled in an object that is resting on the seafloor, and (3) there is a low concentration of expended wires and cables in the HCTT study area. Therefore, it is unlikely that an individual sea turtle would be in close proximity to a sinking wire or cable, and if so, would unlikely become entangled. Potential effects of exposure to cables and wires are not expected to result in population-level effects.

Testing activities under Alternative 1 would expend wires and cables within the Hawaii Study Area and California Study Area.

Based on the numbers and geographic locations of their use, wires and cables used during testing activities are analyzed for their potential to entangle sea turtles. Any species of sea turtle that occurs in the Study Area could at some time encounter expended cables or wires. The sink rates of cables and wires would rule out the possibility of these drifting great distances into nearshore and coastal areas where green, hawksbill, olive ridley, and loggerhead sea turtles are more likely to occur and feed on the bottom. The leatherback sea turtle is more likely to co-occur with these activities, given its preference for open-ocean habitats, but this species is known to forage on jellyfish at or near the surface. Under Alternative 1, exposure to cables and wires used in testing activities may cause short-term or long-term disturbance to an individual turtle because if a sea turtle were to become entangled in a cable or wire, it could free itself, or the entanglement could lead to injury or death. Potential effects of exposure to cable or wire may result in changes to an individual’s behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. However, cables and wires are generally not expected to cause disturbance to sea turtles because of (1) the physical characteristics of the cables and wires, and (2) the behavior of the species, as sea turtles are unlikely to become entangled in an object that is resting on the seafloor. Potential effects of exposure to cables and wires are not expected to result in population-level effects.

The locations of training activities that expend wires and cables are the same under Alternatives 1 and 2. Table 3.0-24 shows the number and location of wires and cables expended during proposed training activities. Even though training activities under Alternative 2 occur at a slightly higher rate and frequency relative to Alternative 1, entanglement stress experienced by reptiles from guidance wires, fiber optic cables, and sonobuoy wires under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. The number of sonobuoys would increase under Alternative 2 training activities, thereby increasing the number of sonobuoy wires expended into the marine environment. However, wires and cables are generally not expected to cause disturbance to sea turtles because (1) sea turtles would only be exposed to potential entanglement risk as the wire or cable sinks through the water column; (2) due to their behavior, sea turtles are unlikely to become entangled in an object that is resting on the seafloor; and (3) there is a low concentration of expended wires and cables in the HCTT study area. Therefore, it is unlikely that an individual sea turtle would be in close proximity to a sinking wire or cable, and if so, would unlikely become entangled. Potential effects of exposure to cables and wires are not expected to result in population-level effects. Further, the differences in species overlap and potential effects from wires and cables on sea turtles during training activities would not be discernible from those described for training activities in Section 3.8.3.5 (Entanglement Stressors). As with Alternative 1, the use of wires and cables in training activities may cause short-term or long-term disturbance to an individual turtle, because if a sea turtle were to become entangled in a cable or wire, it could free itself or the entanglement could lead to injury or death. Potential effects of exposure to cable or wire may result in changes to an individual’s behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. Potential effects of exposure to cables and wires are not expected to result in population-level effects.

The locations of testing activities that expend wires and cables are the same under Alternatives 1 and 2. Table 3.0-24 shows the number and location of wires and cables expended during proposed testing activities. Even though testing activities under Alternative 2 occur at a slightly higher rate and frequency relative to Alternative 1, entanglement stress experienced by reptiles from guidance wires, fiber optic cables, and sonobuoy wires under Alternative 2 are not expected to be meaningfully different than those described under Alternative 1. As with Alternative 1, the use of wires and cables in testing activities may cause short-term or long-term disturbance to an individual turtle, because if a sea turtle were to become entangled in a cable or wire, it could free itself or the entanglement could lead to injury or death. Potential effects of exposure to a cable or wire may result in changes to an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. Potential effects of exposure to cables and wires are not expected to result in population-level effects.

F.8.3.2 Effects from Decelerators/Parachutes

Section 3.0.3.3.5.2 (Decelerators/Parachutes) provides the number of training and testing exercises that involve the use of decelerators/parachutes and the geographic areas where they would be expended. Training and testing activities that introduce decelerators/parachutes into the water column can occur anywhere in the HCTT Study Area and may pose an entanglement risk to sea turtles. Potential effects from decelerators/parachutes as ingestion stressors to sea turtles are discussed in Section 3.8.3.6.1 (Effects from Military Expended Materials).

As described in Section 3.0.3.3.5.2 (Decelerators/Parachutes), decelerators/parachutes used during the proposed activities range in size from 18 in. up to 19–82 ft. in diameter. The vast majority of expended decelerators/parachutes are small (18 in.), cruciform shaped, and used with sonobuoys. Illumination flares use large decelerators/parachutes, up to 19 ft. in diameter. Drones use a larger decelerator/parachute system, ranging from 30 ft. to 82 ft. in diameter. Decelerators/parachutes have short attachment cords and upon impact with water may remain at the surface for 5–15 seconds before sinking to the seafloor, where they flatten. Sonobuoy decelerators/parachutes are designed to sink within 15 minutes, but the rate of sinking depends upon sea conditions and the shape of the decelerator/parachute, and the duration of the descent would depend on the water depth. Unlike the small- and medium-sized decelerators/parachutes, drone decelerators/parachutes do not have weights attached and may remain at the surface or suspended in the water column for some time prior to eventual settlement on the seafloor.

While in the water column, a sea turtle is less likely to become entangled because the decelerator/parachute would have to land directly on the turtle, or the turtle would have to swim into the decelerator/parachute before it sank. Prior to reaching the seafloor, it could be carried along in a current, or snagged on a hard structure near the bottom. Conversely, it could settle to the bottom, where it would be buried by sediment in most soft-bottom areas or colonized by attaching and encrusting organisms, which would further stabilize the material and reduce the potential for reintroduction as an entanglement risk. Decelerators/parachutes or decelerator/parachute lines may be a risk for sea turtles to become entangled, particularly while at the surface. A sea turtle would have to surface to breathe or grab prey from under the decelerator/parachute and swim into the decelerator/parachute or its lines.

If bottom currents are present, the canopy may billow and pose an entanglement threat to sea turtles that feed in benthic habitats (i.e., green, olive ridley, and loggerhead sea turtles). Bottom-feeding sea turtles tend to forage in nearshore areas rather than offshore, where these decelerators/parachutes are used; therefore, sea turtles are not likely to encounter decelerators/parachutes once they reach the seafloor. The potential for a sea turtle to encounter an expended decelerator/parachute at the surface or in the water column is extremely low, and is even less probable at the seafloor, given the general improbability of a sea turtle being near the deployed decelerator/parachute, as well as the general behavior of sea turtles. Depending on how quickly the decelerator/parachute may degrade, the risk may increase with time if the decelerator/parachute remains intact or if underwater currents delay settling of the decelerator/parachute on the seafloor (where they would likely be covered by sediment and encrusted). Factors that may influence degradation times include exposure to ultraviolet radiation and the extent of physical damage of the decelerator/parachute on the water's surface, as well as water temperature and sinking depth. It should be noted that no known instances of sea turtle entanglement with a decelerator/parachute assembly have been reported.

Training activities under Alternative 1 would expend decelerators/parachutes within the Hawaii Study Area, California Study Area, and the Transit Corridor. Based on the numbers and geographic locations of their use, decelerators/parachutes pose a risk of entanglement for all sea turtle species considered in this analysis. Any species of sea turtle that occurs in the Study Area could at some time encounter expended decelerator/parachute. The sink rates of a decelerator/parachute assembly would rule out the possibility of these drifting great distances into nearshore and coastal areas where green, hawksbill, olive ridley, and loggerhead sea turtles are more likely to occur and feed on the bottom. The leatherback is more likely to co-occur with these activities, given its preference for open-ocean habitats, but this species is known to forage on jellyfish at or near the surface. Early juveniles and hatchlings of other sea turtle species (e.g., green sea turtles and loggerheads) may also co-occur with these activities, as well. Under Alternative 1, exposure to decelerators/parachutes used in training activities may cause short-term or long-term disturbance to an individual turtle, because if a sea turtle were to become entangled in a decelerator/parachute, it could free itself, or the entanglement could lead to injury or death. Potential effects of exposure to decelerator/parachute may result in changes to an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. However, decelerators are generally not expected to cause disturbance to sea turtles because the decelerator/parachute would have to land directly on an animal, or an animal would have to swim into it before it sinks. Decelerators/parachutes have small footprints which further reduce the potential for entanglement. It is possible, however, that a benthic feeding sea turtle could become entangled when foraging in areas where decelerators/parachutes have settled on the seafloor. For example, if bottom currents are present, the canopy may temporarily billow and pose a greater entanglement threat.

Pursuant to the ESA, the use of decelerators/parachutes during training activities as described under Alternative 1 would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species, but may affect ESA-listed green, hawksbill, olive ridley, loggerhead, and leatherback sea turtles. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

Testing activities under Alternative 1 would expend decelerators/parachutes within the Hawaii Study Area and California Study Area. Based on the number of decelerators/parachutes expended under Alternative 1 testing activities, the small footprint of impact, and the low likelihood of a decelerator/parachute landing directly on a sea turtle, adverse effects on sea turtles are discountable (unlikely to occur). While entanglement is a serious stressor for sea turtles from a wide range of debris in the ocean, decelerators/parachutes used during military testing activities are an unlikely source. The leatherback is more likely to co-occur with these activities, given its preference for open-ocean habitats; this species is known to forage on jellyfish at or near the surface. Early juveniles and hatchlings of other sea turtle species (e.g., green sea turtles and loggerheads) may also co-occur with these activities, as well.

Pursuant to the ESA, the use of decelerators/parachutes in testing activities as described under Alternative 1 would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species, but may affect ESA-listed green, hawksbill, olive ridley, loggerhead, and leatherback sea turtles. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

F.8.4 Ingestion Stressors

The potential effects from ingesting these materials is dependent upon the probability of the animal encountering these items in their environment, which is primarily contingent on where the items are expended and how a sea turtle feeds. Sea turtles commonly mistake debris for prey. The risk is prolific throughout sea turtle habitats, and ingestion of expended materials by sea turtles could occur in all large marine ecosystems and open ocean areas and can occur at the surface, in the water column, or at the seafloor, depending on the size and buoyancy of the expended object and the feeding behavior of the turtle. Susceptibility of sea turtles to ingestion risk is a factor of the life-stage of the individual sea turtle, foraging habits of the species, the location of the item within the water column, and the type of debris. For example, floating material could be eaten by turtles such as leatherbacks, juveniles, and hatchlings of all species that feed at or near the water surface, while materials that sink to the seafloor pose a risk to bottom-feeding turtles such as loggerheads. The variety of items eaten by juvenile and hatchling sea turtles of all species and adult leatherbacks that feed are prone to ingesting non-prey items (Fujiwara & Caswell, 2001; Hardesty & Wilcox, 2017; Mitchelmore et al., 2017; Schuyler et al., 2014; Schuyler et al., 2016).

The consequences of ingestion could range from temporary and inconsequential to long-term physical stress or even death. Ingestion of these items may not be directly lethal; however, ingestion of plastic and other fragments can restrict food intake and have sublethal effects caused by reduced nutrient intake (McCauley & Bjorndal, 1999). Poor nutrient intake can lead to decreased growth rates, depleted energy, reduced reproduction, and decreased survivorship. These long-term sublethal effects may lead to population-level effects, but this is difficult to assess because the affected individuals remain at sea and the trends may only arise after several generations have passed. Schuyler et al. (2014) determined that most sea turtles, at some point, ingest some amount of debris. Because bottom-feeding occurs in nearshore areas, materials that sink to the seafloor in the open ocean are less likely to be ingested due to their location. While these depths may be within the diving capabilities of most sea turtle species, especially leatherback sea turtles, bottom foraging species (i.e., greens, hawksbills, olive ridleys, and loggerheads) are more likely to forage in the shallower waters less than 100 m in depth. This overlaps with only a small portion of the depth range at which military materials are expended.

F.8.4.1 Effects from Military Expended Materials – Munitions

Many different types of explosive and non-explosive practice munitions are expended at sea during training and testing activities. Types of non-explosive practice munitions generally include projectiles, missiles, and bombs. Of these, only small- or medium-caliber projectiles would be small enough for a sea turtle to ingest. Small- and medium-caliber projectiles include all sizes up to and including 2.25 in. (57 mm) in diameter. These solid metal materials would quickly move through the water column and settle to the seafloor. Ingestion of non-explosive practice munitions is not expected to occur in the water column because the munitions sink quickly. Instead, they are most likely to be encountered by species that forage on the bottom. Types of high-explosive munitions that can result in fragments include demolition charges, projectiles, missiles, and bombs. Fragments would result from fractures in the munitions casing and would vary in size depending on the size of the net explosive weight and munitions type; however, typical sizes of fragments are unknown. These solid metal materials would quickly move through the water column and settle to the seafloor; therefore, ingestion is not expected by most species. Fragments are primarily encountered by species that forage on the bottom. Other military expended materials such as targets, large-caliber projectiles, intact training and testing bombs, guidance wires, 55-gallon drums, sonobuoy tubes, and marine markers are too large for sea turtles to consume.

Sublethal effects due to ingestion of munitions used in training and activities may cause short-term or long-term disturbance to an individual turtle because: (1) if a sea turtle were to incidentally ingest and swallow a projectile or solid metal high-explosive fragment, it could potentially disrupt its feeding behavior or digestive processes; and (2) if the item is particularly large in proportion to the turtle ingesting it, the item could become permanently encapsulated by the stomach lining, with a rare chance that this could impede the turtle's ability to feed or take in nutrients. Potential effects of exposure to munitions may result in changes to an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. In open ocean environments, munitions used in training activities are generally not expected to cause disturbance to sea turtles because: (1) sea turtles are not expected to encounter most small- and medium-caliber projectiles or high-explosive fragments on the seafloor because of the depth at which these would be expended; and (2) in some cases, a turtle would likely pass the projectile through their digestive tract and expel the item without affecting the individual. Because green, loggerhead, olive ridley, and hawksbill sea turtles feed along the seafloor, they are more likely to encounter munitions of ingestible size that settle on the bottom than leatherbacks that primarily feed at the surface and in the water column. Furthermore, these four species typically use nearshore feeding areas, while leatherbacks are more likely to feed in the open ocean. Given the very low probability of a leatherback encountering and ingesting materials on the seafloor, this analysis will focus on green, loggerhead, olive ridley, and hawksbill sea turtles and ingestible materials expended in offshore waters.

In open ocean waters and nearshore habitats, the amount of non-explosive practice munitions and high-explosive munitions fragments that an individual sea turtle would encounter is generally low based on the patchy distribution of both the projectiles and sea turtle feeding habits. In addition, a sea turtle would not likely ingest every projectile it encountered. Furthermore, a sea turtle may attempt to ingest a projectile or fragment and then reject it when it realizes it is not a food item. Therefore, potential effects of non-explosive practice munitions and fragments ingestion would be limited to the unlikely event in which a sea turtle might suffer a negative response from ingesting an item that becomes embedded in tissue or is too large to be passed through the digestive system. Sea snakes would have to mistake an item as prey, and would only be exposed in pelagic habitats, but would experience similar effects as sea turtles. The Navy considers the likelihood of ingestion of military expended materials by sea turtles or sea snakes to be very low.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs and precious coral beds) to avoid potential effects from military expended materials on seafloor resources in mitigation areas throughout the Study Area. This mitigation will consequently help avoid potential effects on benthic foraging sea turtles that feed on shallow-water coral reefs and precious coral beds.

F.8.4.2 Effects from Military Expended Materials Other Than Munitions

Training

As presented in Section 3.0.3.3.6 (Ingestion Stressors), military expended materials other than munitions would be expended during offshore training activities within the Hawaii Study Area and California Study Area.

Target-related material, chaff, flares, and decelerators/parachutes (and their subcomponents) have the potential to be ingested by a sea turtle, although that is considered unlikely since most of these materials would quickly drop through the water column, settle on the seafloor, or rapidly decay, and not present an ingestion hazard. Some Styrofoam, plastic endcaps, chaff, and other small items may float for some time before sinking.

While the smaller items discussed here may pose a hazard to sea turtles, as discussed for non-explosive practice munitions ingestion, the effects of ingesting these forms of expended materials on sea turtles would be minor because of the following factors:

- the limited geographic area where materials other than munitions are expended during a given event
- the limited period of time these military expended materials would remain in the water column
- the unlikely chance that a sea turtle might encounter and swallow these items on the seafloor, particularly given that many of these items would be expended over deep, offshore waters

The effects of ingesting military expended materials other than munitions would be limited to cases where an individual sea turtle might eat an indigestible item too large to be passed through the gut. The sea turtle would not be preferentially attracted to these military expended materials, with the possible exception of decelerators/parachutes that may appear similar to the prey of some sea turtle species and life stages that feed on jellyfish and similar organisms. For the most part, these military expended materials would most likely only be incidentally ingested by individuals feeding on the bottom in the precise location where these items were deposited. Non-munition military expended materials that would remain floating on the surface are too small to pose a risk of intestinal blockage to any sea turtle that happened to encounter it. Because leatherbacks and juveniles of some species (e.g., green sea turtles) are more likely to feed at or near the surface, they are more likely to encounter materials at the surface than are other species of turtles that primarily feed along the seafloor. Furthermore, leatherbacks typically feed in the open ocean, while other species are more likely to feed in nearshore areas. Though they are bottom-feeding species that generally feed nearshore, green, hawksbill, olive ridley, and loggerhead sea turtles may occur in the open ocean during migrations, as well as hatchling and juvenile stage turtles.

Sublethal effects due to ingestion of military expended materials other than munitions used in training activities may cause short-term or long-term disturbance to an individual turtle because (1) if a sea turtle were to incidentally ingest and swallow a decelerator/parachute, target fragment, chaff or flare component, it could potentially disrupt its feeding behavior or digestive processes; and (2) if the item is particularly large in proportion to the turtle ingesting it, the item could become permanently encapsulated by the stomach lining, with a rare chance that this could impede the turtle's ability to feed or take in nutrients. Potential effects of exposure to these items may result in changes to an individual's behavior, growth, survival, annual reproductive success, lifetime reproductive success (fitness), or species recruitment. However, decelerators/parachutes, target fragments, chaff, and flare components used in training activities are generally not expected to cause disturbance to sea turtles because (1) leatherbacks are likely to forage further offshore than within range complexes, and other sea turtles primarily forage on the bottom in nearshore areas; (2) in some cases, a turtle would likely pass the item through its digestive tract and expel the item without affecting the individual; and (3) chaff, if ingested, would occur in very low concentration and is similar to spicules, which sea turtles (species and life stages that consume sponges and other organisms containing spicules) ingest without harm. Potential effects of exposure to military expended materials other than munitions are not expected to result in population-level effects.

Pursuant to the ESA, the use of military expended materials other than munitions during training activities as described under Alternative 1 would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species, but may affect ESA-listed green, hawksbill, olive ridley, loggerhead, and leatherback sea turtles. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

Testing

As presented in Section 3.0.3.3.6 (Ingestion Stressors) military expended materials other than munitions would be expended during testing activities within the Hawaii Study Area and California Study Area. Target-related material, chaff, flares, and decelerators/parachutes (and their subcomponents) have the potential to be ingested by a sea turtle, although that is considered unlikely since most of these materials would quickly drop through the water column, and settle on the seafloor. Some Styrofoam, plastic endcaps, chaff, and other small items may float for some time before sinking.

While the smaller items discussed here may pose a hazard to sea turtles, as discussed for non-explosive practice munitions ingestion, the effects of ingesting these forms of expended materials on sea turtles would be minor because of the following factors:

- the limited geographic area where materials other than munitions are expended during a given event
- the limited period of time these military expended materials would remain in the water column
- the unlikely chance that a sea turtle might encounter and swallow these items on the seafloor, particularly given that many of these items would be expended over deep, offshore waters

The effects of ingesting military expended materials other than munitions would be limited to cases where an individual sea turtle might eat an indigestible item too large to be passed through the gut. The sea turtle would not be preferentially attracted to these military expended materials, with the possible exception of decelerators/parachutes that may appear similar to the prey of some sea turtle species and life stages that feed on jellyfish and similar organisms. For the most part, these military expended materials would most likely only be incidentally ingested by individuals feeding on the bottom in the precise location where these items were deposited. Non-munition military expended materials that would remain floating on the surface are too small to pose a risk of intestinal blockage to any sea turtle that happened to encounter it. Because leatherbacks and juveniles of some species (e.g., green sea turtles) are more likely to feed at or near the surface, they are more likely to encounter materials at the surface than are other species of turtles that primarily feed along the seafloor. Furthermore, leatherbacks typically feed in the open ocean, while other species are more likely to feed in nearshore areas. Though they are bottom-feeding species that generally feed nearshore, green, hawksbill, olive ridley, and loggerhead sea turtles may occur in the open ocean during migrations, as well as hatchling and juvenile stage turtles.

Pursuant to the ESA, the use of military expended materials other than munitions during testing activities as described under Alternative 1 would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species, but may affect ESA-listed green, hawksbill, olive ridley, loggerhead, and leatherback sea turtles. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

Target-Related Materials

At-sea targets are usually remotely operated airborne, surface, or subsurface traveling units, most of which are designed to be recovered for reuse. If they are severely damaged or displaced, targets may sink before they can be retrieved. Expendable targets include air-launched decoys, marine markers (smoke floats), cardboard boxes, and 10 ft. diameter red balloons tethered by a sea anchor. Most target fragments would sink quickly in the sea. Floating material, such as Styrofoam, may be lost from target boats and remain at the surface for some time, however during target recovery, personnel would collect as much floating debris and Styrofoam as possible.

Chaff

Chaff is an electronic countermeasure designed to reflect radar waves and obscure aircraft, vessels, and other equipment from radar tracking sources. Chaff is composed of an aluminum alloy coating on glass fibers of silicon dioxide (U.S. Air Force, 1997). It is released or dispensed in cartridges or projectiles that contain millions of chaff fibers. When deployed, a diffuse cloud of fibers undetectable to the human eye is formed. Chaff is a very light material that can remain suspended in air anywhere from 10 minutes to 10 hours and can travel considerable distances from its release point, depending on prevailing atmospheric conditions (Arfsten et al., 2002; U.S. Air Force, 1997). Doppler radar has tracked chaff plumes containing approximately 900 grams (g) of chaff drifting 200 mi. from the point of release, with the plume covering greater than 400 cubic miles (1,667 cubic kilometers) (Arfsten et al., 2002).

The chaff concentrations that sea turtles could be exposed to following release of multiple cartridges (e.g., following a single day of training) are difficult to accurately estimate because it depends on several unknown factors. First, specific release points are not recorded and tend to be random, and chaff dispersion in air depends on prevailing atmospheric conditions. After falling from the air, chaff fibers would be expected to float on the sea surface for some period, depending on wave and wind action. The fibers would be dispersed further by sea currents as they float and slowly sink toward the bottom. Chaff concentrations in benthic habitats following release of a single cartridge would be lower than the values noted in this section, based on dispersion by currents and the enormous dilution capacity of the receiving waters.

Several literature reviews and controlled experiments have indicated that chaff poses little risk, except at concentrations substantially higher than those that could reasonably occur from military training (Arfsten et al., 2002; Spargo, 1999; U.S. Air Force, 1997). Nonetheless, some sea turtle species within the Study Area could be exposed to chaff through direct body contact and ingestion. Chemical alteration of water and sediment from decomposing chaff fibers is not expected to result in exposure. Based on the dispersion characteristics of chaff, it is likely that sea turtles would occasionally come in direct contact with chaff fibers while at the water’s surface and while submerged, but such contact would be inconsequential. Chaff is similar to fine human hair (U.S. Air Force, 1997). Because of the flexibility and softness of chaff, external contact would not be expected to affect most wildlife (U.S. Air Force, 1997), and the fibers would quickly wash off shortly after contact. Given the properties of chaff, skin irritation is not expected to be a problem (U.S. Air Force, 1997). Arfsten et al. (2002); Spargo (1999); U.S. Air Force

(1997) reviewed the potential effects of chaff inhalation on humans, livestock, and animals and concluded that the fibers are too large to be inhaled into the lung. The fibers are predicted to be deposited in the nose, mouth, or trachea and are either swallowed or expelled; however, these reviews did not specifically consider sea turtles.

Although chaff fibers are too small for sea turtles to confuse with prey and forage, there is some potential for chaff to be incidentally ingested along with other prey items, particularly if the chaff attaches to other floating marine debris. If ingested, chaff is not expected to affect sea turtles due to the low concentration that would be ingested and the small size of the fibers. While no similar studies to those discussed in Section 3.0.3.3.6.3 (Military Expended Materials) on the effects of chaff have been conducted on sea turtles, they are also not likely to be affected by incidental ingestion of chaff fibers. For instance, some sea turtles ingest spicules (small spines within the structure of a sponge) in the course of eating the sponges, without harm to their digestive system. Since chaff fibers are of similar composition and size as these spicules (Spargo, 1999), ingestion of chaff should be inconsequential for sea turtles.

Chaff cartridge plastic end caps and pistons would also be released into the marine environment, where they would persist for long periods and could be ingested by sea turtles while initially floating on the surface and sinking through the water column. Chaff end caps and pistons would eventually sink in saltwater to the seafloor (Spargo, 2007), which reduces the likelihood of ingestion by sea turtles at the surface or in the water column.

Flares

Flares are designed to burn completely. The only material that would enter the water would be a small, round, plastic compression pad or piston (0.45–4.1 g depending on flare type). The flare pads and pistons float in sea water.

An extensive literature review and controlled experiments conducted by the United States Air Force demonstrated that self-protection flare use poses little risk to the environment or animals (U.S. Air Force, 1997). For sea turtles and sea snakes, these types of flares are large enough to not be considered an ingestion hazard. Nonetheless, sea turtles within the vicinity of flares could be exposed to light generated by the flares. It is unlikely that sea turtles or sea snakes would be exposed to any chemicals that produce either flames or smoke since these components are consumed in their entirety during the burning process. Animals are unlikely to approach or get close enough to the flame to be exposed to any chemical components.

Decelerators/Parachutes

As noted previously in Section 3.0.3.3.5.2 (Decelerators/Parachutes), decelerators/parachutes are classified into four different categories based on size: small, medium, large, and extra-large. The majority of expended decelerators/parachutes are in the small category. Decelerators/parachutes in the three remaining size categories (medium – up to 19 ft. in diameter, large – between 30 and 50 ft. in diameter, and extra-large – up to 80 ft.in diameter) are likely too big to be mistaken for prey items and ingested by a sea turtle or sea snake.

The majority of decelerators/parachutes are weighted and by design must sink below the surface within five minutes of contact with the water. Once on the seafloor, decelerators/parachutes become flattened (Environmental Sciences Group, 2005b). Ingestion of a decelerator/parachute by a sea turtle or sea snake at the surface or within the water column would be unlikely, since the decelerator/parachute would not be available for very long before it sinks. Once on the seafloor, if bottom currents are present, the canopy may temporarily billow and be available for potential ingestion by a sea turtle feeding on or near the seafloor (sea snakes are not benthic foragers, and therefore would not be exposed to ingestion risk of decelerators/parachutes on the seafloor). Conversely, the decelerator/parachute could be buried by sediment in most soft bottom areas or colonized by attaching and encrusting organisms, which would further stabilize the material and reduce the potential for an ingestion risk. Some decelerators/parachutes may be too large to be a potential prey item for certain age classes (e.g., hatchlings and pre-recruitment juveniles), although degradation of the decelerator/parachute may create smaller items that are potentially ingestible. The majority of these items (from sonobuoys), however, would be expended in deep offshore waters. Bottom-feeding sea turtles (e.g., green, hawksbill, olive ridley, and loggerhead turtles) tend to forage in nearshore and coastal areas rather than offshore, where the majority of these decelerators/parachutes are used. Since these materials would most likely be expended in offshore waters too deep for benthic foraging, it would be unlikely for bottom-foraging sea turtles to interact with these materials once they sink; therefore, it is unlikely that sea turtles would encounter decelerators/parachutes once they reach the seafloor.

F.8.5 Secondary Stressors

This section analyzes potential effects on reptiles exposed to stressors indirectly through effects on habitat and prey availability.

Explosives

Underwater explosions could affect other species in the food web, including sea turtle and sea snake prey species, and could disrupt ecological relationships and conditions that would lead to decreased availability of forage. The effects of explosions would differ depending on the type of prey species in the area of the blast. As described in Chapter 2 (Description of Proposed Action and Alternatives), Table 2.6-1 through Table 2.6-5, training and testing activities resulting in underwater explosions will occur in the Study Area.

In addition to the physical effects of an underwater blast (e.g., injury or mortality from the blast pressure wave), prey might have behavioral reactions to underwater sound. For instance, prey might exhibit a strong startle reaction to detonations that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals (Mather, 2004). The abundance of prey near the detonation point could be diminished for a short period before being repopulated by animals from adjacent waters (Berglind et al., 2009; Craig, 2001). Many sea turtle prey items, such as jellyfish, sponges, and molluscs, have limited mobility and ability to react to pressure waves; therefore, mobile prey species for sea turtles and sea snakes would be less affected because of their ability to respond to other stressors preceding an underwater blast (e.g., vessel noise or visual cues). Any of these scenarios would be temporary, only occurring during activities involving explosives, and no lasting effect on prey availability or the pelagic food web would be expected. For example, if prey were removed from an area resulting from a stressor introduced by a training or testing activity, prey species would be expected to return to or recolonize rapidly in the area because there would be little or no permanent change to the habitat.

The Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential effects from explosives and physical disturbance and strike stressors on seafloor resources in mitigation areas throughout the Study Area. This mitigation will consequently help avoid potential effects from explosives on sea turtle and sea snake prey species that inhabit shallow-water coral reefs, live hard bottom, precious coral beds, artificial reefs, and shipwrecks.

Explosion Byproducts and Unexploded Munitions

High-order explosions consume most of the explosive material, creating typical combustion products. In the case of Royal Demolition Explosive, also known as cyclonite and hexogen, 98 percent of the byproducts are common seawater constituents, and the remainder is rapidly diluted below threshold effect level (Section 3.2, Sediments and Water Quality). Explosion byproducts associated with high-order detonations present no indirect stressors to sea turtles or sea snakes through sediment or water. Furthermore, most explosions occur in depths exceeding those which normally support seagrass beds and coral reefs, areas that are commonly used by green and hawksbill sea turtles. For example, most detonations would occur in waters greater than 200 ft. in depth, and greater than 3 NM from shore, although mine warfare, demolition, and some testing detonations would occur in shallow water close to shore. These low-order detonations and unexploded munitions present elevated likelihood of secondary effects on sea turtles. For sea snakes, deep diving to these depths is not likely, and they would not be exposed to indirect stressors from explosion byproducts or unexploded munitions.

Deposition of undetonated explosive materials into the marine environment can be reasonably well estimated by the known failure and low-order detonation rates of high explosives (Section 3.2, Sediments and Water Quality, Table 3.2-10). While it is remotely possible for sea turtles to come into contact with an undetonated explosive, to have contact with unexploded materials in the sediment or water, and or to ingest unexploded materials in sediments, it is very unlikely. For sea snakes, benthic foraging in pelagic environments is unlikely to occur, and interactions with undetonated explosives is highly unlikely.

Indirect effects by explosives and unexploded munitions to sea turtles via sediment contamination would only be possible only if a sea turtle ingested the sediment. Degradation of explosives proceeds through several pathways, as discussed in Section 3.2.3.1 (Explosives Stressors). Degradation products of Royal Demolition Explosive are not toxic to marine organisms at realistic exposure levels (Rosen & Lotufo, 2010). Relatively low solubility of most explosives and their degradation products means that concentrations of these contaminants in the marine environment are relatively low and readily diluted. Furthermore, while explosives and their degradation products were detectable in marine sediment approximately 6–12 in. away from degrading munitions, the concentrations of these compounds were not statistically distinguishable from background beyond 3–6 ft. from the degrading munitions (Section 3.2.3.1, Explosives Stressors). Taken together, it is possible that sea turtles could be exposed to degrading explosives, but it would be within a very small radius of the explosive (1 to 6 ft.). Sea snakes, with shallow water pelagic habits, would not likely interact with sediments.

A series of research efforts focused on World War II underwater munitions disposal sites in Hawaii (Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016; University of Hawaii, 2010) and an intensively used live fire range in the Mariana Islands (Smith & Marx, 2016) provide information in regard to the effects of undetonated materials and unexploded munitions on marine life. Section 3.2.3.1 (Explosives and Explosives Byproducts) and Section 3.2.3.2 (Metals) contains a summary of this literature that investigated water and sediment quality effects, on a localized scale, from munitions ocean disposal sites and ocean disposed dredge spoils sites. Findings from these studies indicate that there were no adverse effects on the local ecology from the presence of degrading munitions and there was no bioaccumulation of munitions-related chemicals in local marine species.

The island of Farallon De Medinilla (in the Mariana Islands) has been used as a target area since 1971. Between 1997 and 2012, there were 14 underwater scientific survey investigations around the island providing a long-term look at potential effects on the marine life from training and testing involving the use of munitions (Smith & Marx, 2016). Munitions use has included high-explosive rounds from gunfire, high-explosives bombs by Navy aircraft and U.S. Air Force B-52s, in addition to the expenditure of inert rounds and non-explosive practice bombs. Marine life assessed during these surveys included algae, corals, benthic invertebrates, sharks, rays, and bony fishes, and sea turtles. The investigators found no evidence over the 16-year period that the condition of the biological resources had been adversely affected to a significant degree by the training activities (Smith & Marx, 2016). Furthermore, they found that the health, abundance, and biomass of fishes, corals and other marine resources were comparable to or superior to those in similar habitats at other locations within the Mariana Archipelago.

These findings are consistent with other assessments such as that done for the Potomac River Test Range at Dahlgren, Virginia, which was established in 1918 and is the nation's largest fully instrumented, over-the-water gun-firing range. Munitions tested at Naval Surface Warfare Center, Dahlgren have included rounds from small-caliber guns up to the Navy's largest (16 in. guns), bombs, rockets, mortars, grenades, mines, depth charges, and torpedoes (U.S. Department of the Navy, 2013f). Results from the assessment indicate that munitions expended at Naval Surface Warfare Center, Dahlgren have not contributed to significant concentrations of metals to the Potomac River water and sediments, given those contributions are orders of magnitude lower than concentrations already present in the Potomac River from natural and manmade sources (U.S. Department of the Navy, 2013f).

The concentration of munitions/explosions, expended material, or devices in any one location in the HCTT Study Area would be a small fraction of that from a World War II dump site, or a target island used for 45 years, or a water range in a river used for almost 100 years. Based on findings from much more intensively used locations, the water quality effects from the use of munitions, expended material, or devices resulting from any of the proposed actions would be negligible by comparison. As a result, explosion by-products and unexploded munitions would have no meaningful effect on water quality and would therefore not constitute a secondary indirect stressor for sea turtles or sea snakes.

Metals

Metals are introduced into seawater and sediments as a result of training and testing activities involving ship hulks, targets, munitions, and other military expended materials (see Section 3.2.3.2, Metals) (Environmental Sciences Group, 2005b). Some metals bioaccumulate and physiological effects begin to occur only after several trophic transfers concentrate the toxic metals (Section 3.2 Sediments and Water Quality; and Chapter 4, Cumulative Effects). Evidence from a number of studies (Briggs et al., 2016; Edwards et al., 2016; Kelley et al., 2016; Koide et al., 2016) indicate metal contamination is very localized and that bioaccumulation resulting from munitions cannot be demonstrated. Specifically, in sampled marine life living on or around munitions on the seafloor, metal concentrations could not be definitively linked to the munitions since comparison of metals in sediment next to munitions show relatively little difference in comparison to other "clean" marine sediments used as a control/reference (Koide et al., 2016). Research has demonstrated that some smaller marine organisms are attracted to metal munitions as a hard substrate for colonization or as shelter (Kelley et al., 2015) (Smith & Marx, 2016). Although this would likely increase prey availability for some benthic foraging sea turtles that feed on molluscs (e.g., loggerheads), the relatively low density of metals deposited by training and testing activities compared to concentrated dump and range sites would not likely substantively benefit sea turtles. As stated above, pelagic habits and shallow water diving would not likely present any opportunities for sea snake interactions with metal contaminated sediments.

Chemicals

Several Navy training and testing activities introduce chemicals into the marine environment that are potentially harmful in higher concentrations; however, rapid dilution would occur, and toxic concentrations are unlikely to be encountered. Chemicals introduced are principally from flares and propellants for missiles and torpedoes. Properly functioning flares, missiles, and torpedoes combust most of their propellants, leaving benign or readily diluted soluble combustion byproducts (e.g., hydrogen cyanide). Operational failures may allow propellants and their degradation products to be released into the marine environment. Flares and missile that operationally fail may release perchlorate, which is highly soluble in water, persistent, and affects metabolic processes in many plants and animals if in sufficient concentration. Such concentrations are not likely to persist in the ocean. Research has demonstrated that perchlorate did not bioconcentrate or bioaccumulate, which was consistent with the expectations for a water-soluble compound (Furin et al., 2013). Perchlorate from failed expendable items is therefore unlikely to compromise water quality to that point that it would act as a secondary stressor to sea turtles. It should also be noted that chemicals in the marine environment as a result of Navy training and testing activities would not occur in isolation and are typically associated with military expended materials that release the chemicals while in operation. Because sea turtles and sea snakes would likely avoid expended flares, missiles, or torpedoes in the water (because of other cues such as visual and noise disturbance), avoidance would further reduce the potential for introduced chemicals to act as a secondary stressor.

F.8.5.1 Effects on Habitat

As presented in Section F.7.5 (Secondary Stressors), Navy activities that introduce explosive byproducts and unexploded munitions, metals, and chemicals into the marine environment have not demonstrated long-term effects on sediment and water quality. Explosive byproducts and unexploded munitions from ongoing Navy activities have not resulted in water quality effects, and the likelihood of sea turtles or sea snakes being in contact with sediments contaminated from degrading explosives is low, given the small radius of impact around the location of the explosive. Furthermore, there is no evidence of bioconcentration or bioaccumulation of chemicals introduced by Navy activities that would alter water quality to an extent that would result in overall habitat degradation for sea turtles or sea snakes.

As stated previously, most detonations would occur in waters greater than 200 ft. in depth, and greater than 3 NM from shore, although mine warfare, demolition, and some testing detonations would occur in shallow water close to shore. In deep waters, explosions would not likely affect habitat for sea turtles or sea snakes because the explosion would not be on or proximate to the sea floor. In nearshore waters, explosions would typically occur in the same locations, limiting the removal of habitat to previously disturbed areas. Therefore, habitat loss from training and testing activities that use explosions would not substantially remove habitats available to sea turtles and sea snakes and not affect sea turtle or sea snake individuals or populations.

Pursuant to the ESA, training and testing activities that introduce secondary stressors would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species, but may affect ESA-listed green, hawksbill, olive ridley, loggerhead, and leatherback sea turtles through minor and localized indirect effects on these species' habitat. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

F.8.5.2 Effects on Prey Availability

As presented above in Section F.7.5 (Secondary Stressors), Navy activities that introduce explosives, metals, and chemicals into the marine environment have not demonstrated long-term effects on prey availability for sea turtles or sea snakes. Bioaccumulation of metals from munitions in prey species has not been demonstrated, and no effects to prey availability from metals and chemicals are known to occur.

Training and testing activities in the HCTT Study Area would be unlikely to affect coral reefs (a direct and indirect source of prey and forage items for sea turtles) because the Navy implements mitigation for shallow-water coral reefs. These mitigation measures would continue under both Alternative 1 and Alternative 2.

Pursuant to the ESA, training and testing activities that introduce secondary stressors would have no effect on leatherback sea turtle critical habitat because activities would not occur within the designated critical habitat for this species but may affect ESA-listed sea turtles through minor and localized indirect effects on these species' prey availability. The Navy has consulted with NMFS as required by section 7(a)(2) of the ESA.

F.8.5.3 Summary of Potential Effects on Reptiles

Additive Stressors– There are generally two ways that a sea turtle or sea snake could be exposed to multiple additive stressors. The first would be if an animal were exposed to multiple sources of stress from a single event or activity (e.g., a mine warfare event may include the use of a sound source and a vessel).

The potential for a combination of these effects from a single activity would depend on the range to effects of each of the stressors and the response or lack of response to that stressor. Most of the activities proposed under Alternative 1 generally involve the use of moving platforms (e.g., ships, torpedoes, aircraft) that may produce one or more stressors; therefore, it is likely that if a sea turtle or sea snake were within the potential effects range of those activities, it may be affected by multiple stressors simultaneously. Individual stressors that would otherwise have minimal to no effect, may combine to cause a response. However, due to the wide dispersion of stressors, speed of the platforms, general dynamic movement of many training and testing activities, and behavioral avoidance exhibited by sea turtles, it is very unlikely that a sea turtle or sea snake would remain in the potential effects range of multiple sources or sequential exercises. Exposure to multiple stressors is more likely to occur at an instrumented range where training and testing using multiple platforms may be concentrated during a particular event. In such cases involving a relatively small area on an instrumented range, a behavioral reaction resulting in avoidance of the immediate vicinity of the activity would reduce the likelihood of exposure to additional stressors. Nevertheless, the majority of the proposed activities are unit-level training and small testing activities which are conducted in the open ocean. Unit level exercises occur over a small spatial scale (one to a few square miles) and with few participants (usually one or two vessels) or short duration (the order of a few hours or less).

Secondly, a sea turtle or sea snake could be exposed to multiple training and testing activities over the course of its life, however, training and testing activities are generally separated in space and time in such a way that it would be unlikely that any individual sea turtle or sea snake would be exposed to stressors from multiple activities within a short timeframe. However, sea turtles with a home range intersecting an area of concentrated Navy activity have elevated exposure risks relative to sea turtles that simply transit the area through a migratory corridor. Sea snakes in open ocean environments within the Study Area are more associated with currents without home ranges in pelagic areas; therefore, activities concentrated in repeated geographic locations would not present a risk to pelagic roaming sea snakes. This limited potential for exposure of individuals is not anticipated to affect populations.

Synergistic Stressors–Multiple stressors may also have synergistic effects on sea turtles. Assumed to rarely occur in the Study Area, and not occurring within groups, sea snakes would likely not experience synergistic effects. Sea turtles that react to a sound source (behavioral response) or experience injury from acoustic stressors could be more susceptible to physical strike and disturbance stressors via a decreased ability to detect and avoid threats. Sea turtles that experience behavioral and physiological consequences of ingestion stressors could be more susceptible to entanglement and physical strike stressors via malnourishment and disorientation. Similarly, sea turtles that may be weakened by disease (e.g., fibropapillomatosis) or other factors that are not associated with Navy training and testing activities may be more susceptible to stressors analyzed in this EIS. These interactions are speculative, and without data on the combination of multiple Navy stressors, the synergistic effects from the combination of Navy stressors are difficult to predict in any meaningful way. Research and monitoring efforts have included before, during, and after-event observations and surveys, data collection through conducting long-term studies in areas of Navy activity, occurrence surveys over large geographic areas, biopsy of animals occurring in areas of Navy activity, and tagging studies where animals are exposed to Navy stressors. These efforts are intended to contribute to the overall understanding of what effects may be occurring overall to animals in these areas. To date, the findings from the research and monitoring and the regulatory conclusions from previous analyses by NMFS (National Oceanic and Atmospheric Administration, 2013; National Oceanic and Atmospheric Administration, 2015) are that majority of effects from Navy training and testing activities are not expected to have deleterious effects on the fitness of any individuals or long-term consequences to populations of sea turtles.

Although potential effects on certain sea turtle species from training and testing activities under Alternative 1 may include injury to individuals, those injuries are not expected to lead to consequences for populations. The potential effects anticipated from Alternative 1 are summarized in Sections 3.8.4 (Endangered Species Act Determinations). For a discussion of cumulative effects, see Chapter 4 (Cumulative Effects).

F.9 Birds

F.9.1 Acoustic Stressors

F.9.1.1 Background

The sections below include a survey and synthesis of best-available-science published in peer-reviewed journals, technical reports, and other scientific sources pertinent to effects on birds potentially resulting from sound-producing Navy training and testing activities. Effects on birds depends on the sound source and context of exposure. Possible effects include auditory or non-auditory trauma, hearing loss resulting in temporary or permanent hearing threshold shift, auditory masking, physiological stress, or changes in behavior, including changing habitat use and activity patterns, increasing stress response, decreasing immune response, reducing reproductive success, increasing predation risk, and degrading communication (Larkin et al., 1996). Numerous studies have documented that birds and other wild animals respond to human-made noise (Bowles et al., 1994; Larkin et al., 1996; National Park Service, 1994). The manner in which birds respond to noise could depend on species physiology life stage, characteristics of the noise source, loudness, onset rate, distance from the noise source, presence/absence of associated visual stimuli, and previous exposure. Noise may cause physiological or behavioral responses that reduce the animals' fitness or ability to grow, survive, and reproduce successfully.

The types of birds exposed to sound-producing activities depend on where training and testing activities occur. Birds in the study area can be divided into three groups based on breeding and foraging habitat: (1) those species such as albatrosses, petrels, frigatebirds, tropicbirds, boobies, alcids, and some terns that forage over the ocean and nest on oceanic islands; (2) species such as pelicans, cormorants, gulls, and some terns that nest along the coast and forage in nearshore areas; and (3) those few species such as skuas, jaegers, Franklin's gull, Bonaparte's gulls, ring-billed gulls, black terns, and ducks and loons that nest and forage in inland habitats and come to the coastal areas during nonbreeding seasons. In addition, birds that are typically found inland, such as songbirds, may be present flying in large numbers over open ocean areas during annual spring and fall migration periods.

Birds could be exposed to sounds from a variety of sources. While above the water surface, birds may be exposed to airborne sources such as pile driving, weapons noise, vessel noise, and aircraft noise. While foraging and diving, birds may be exposed to underwater sources such as sonar, pile driving, air guns, and vessel noise. While foraging birds will be present near the water surface, migrating birds may fly at various altitudes. Some species such as sea ducks and loons may be commonly seen flying just above the water's surface, but the same species can also be spotted flying high enough (5,800 ft.) that they are barely visible through binoculars (Lincoln et al., 1998). While there is considerable variation, the favored altitude for most small birds appears to be between 500 ft. (152 m) and 1,000 ft. (305 m). Radar studies have demonstrated that 95 percent of the migratory movements occur at less than 10,000 ft. (3,050 m), with the bulk of the movements occurring under 3,000 ft. (914 m) (Lincoln et al., 1998).

Seabirds use a variety of foraging behaviors that could expose them to underwater sound. Most seabirds plunge-dive from the air into the water or perform aerial dipping (the act of taking food from the water surface in flight); others surface-dip (swimming and then dipping to pick up items below the surface) or jump-plunge (swimming, then jumping upward and diving underwater). Birds that feed at the surface by surface or aerial dipping with limited to no underwater exposure include petrels, jaegers, and phalaropes. Birds that plunge-dive are typically submerged for short durations, and any exposure to underwater sound would be very brief. Birds that plunge-dive include albatrosses, some tern species, masked boobies, gannets, shearwaters, and tropicbirds. Some birds, such as cormorants, seaducks, alcids, and loons pursue prey under the surface, swimming deeper and staying underwater longer than other plunge-divers. Some of these birds may stay underwater for up to several minutes and reach depths between 50 ft. (15 m) and 550 ft. (168 m) (Alderfer, 2003; Durant et al., 2003; Jones, 2001; Lin, 2002; Ronconi, 2001). Birds that forage near the surface would be exposed to underwater sound for shorter periods of time than those that forage below the surface. Exposures of birds that forage below the surface may be reduced by destructive interference of reflected sound waves near the water surface (see Appendix D, Acoustic and Explosive Concepts). Sounds generated underwater during training and testing would be more likely to affect birds that pursue prey under the surface, although as previously stated, little is known about seabird hearing ability underwater.

F.9.1.1.1 Injury

Auditory structures can be susceptible to direct mechanical injury due to high levels of impulsive sound. This could include tympanic membrane rupture, disarticulation of the middle ear ossicles, and trauma to the inner ear structures such as hair cells within the organ of Corti. Auditory trauma differs from auditory fatigue in that the latter involves the overstimulation of the auditory system, rather than direct mechanical damage, which may result in hearing loss. There are no data on damage to the middle ear structures of birds due to acoustic exposures. Because birds are known to regenerate auditory hair cells, studies have been conducted to purposely expose birds to very high sound exposure levels (SELs) in order to induce hair cell damage in the inner ear. Because damage can co-occur with fatiguing exposures at high SELs, effects to hair cells are discussed below F.8.1.1.2 (Hearing Loss).

Because there is no data on non-auditory injury to birds from intense non-explosive sound sources, it may be useful to consider information for other similar-sized vertebrates. The rapid large pressure changes near non-explosive impulsive underwater sound sources, such as some large air guns and pile driving, are thought to be potentially injurious to other small animals (fishes and sea turtles). While long-duration exposures (i.e., minutes to hours) to high sound levels of sonars are thought to be injurious to fishes, this has not been experimentally observed [see Popper et al. (2014)]. Potential for injury is generally attributed to compression and expansion of body gas cavities, either due to rapid onset of pressure changes or resonance (enhanced oscillation of a cavity at its natural frequency). Because water is considered incompressible and animal tissue is generally of similar density as water, animals would be more susceptible to injury from a high-amplitude sound source in water than in air since waves would pass directly through the body rather than being reflected. Proximal exposures to high-amplitude non-impulsive sounds underwater could be limited by a bird's surfacing response.

In air, the risk of barotrauma would be associated with high-amplitude impulses, such as from explosives (discussed in Section 3.8.3.2, Explosive Stressors). Unlike in water, most acoustic energy will reflect off the surface of an animal's body in air. Plus, air is compressible whereas water is not, allowing energy to dissipate more rapidly. For these reasons, in-air non-explosive sound sources in this analysis are considered to pose little risk of non-auditory injury.

F.9.1.1.2 Hearing Loss

Exposure to intense sound may result in hearing loss which persists after cessation of the noise exposure. Hearing loss may be temporary or permanent, depending on factors such as the exposure frequency, received sound pressure level (SPL), temporal pattern, and duration. Hearing loss could impair a bird's ability to hear biologically important sounds within the affected frequency range. Biologically important sounds come from social groups, potential mates, offspring, or parents; environmental sounds; prey; or predators.

Because in-air measures of hearing loss and recovery in birds due to an acoustic exposure are limited [e.g., quail, budgerigars, canaries, and zebra finches (Ryals et al., 1999); budgerigar (Hashino et al., 1988); parakeet (Saunders & Dooling, 1974); quail (Niemiec et al., 1994)] and no studies exist of bird hearing loss due to underwater sound exposures, auditory threshold shift in birds is considered to be consistent with general knowledge about noise-induced hearing loss described in the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (see Section F.1.1). The frequencies affected by hearing loss would vary depending on the exposure frequency. The limited data on hearing loss in birds shows that the frequency of exposure is the hearing frequency most likely to be affected (Saunders & Dooling, 1974).

Hearing loss can be due to biochemical (fatiguing) processes or tissue damage. Tissue damage can include damage to the auditory hair cells and their underlying support cells. Hair cell damage has been observed in birds exposed to long duration sounds that resulted in initial threshold shifts greater than 40 dB (Niemiec et al., 1994; Ryals et al., 1999). Unlike many other animals, birds have the ability to regenerate hair cells in the ear, usually resulting in considerable anatomical, physiological, and behavioral recovery within several weeks (Rubel et al., 2013; Ryals et al., 1999). Still, intense exposures are not always fully recoverable, even over periods up to a year after exposure, and damage and subsequent recovery vary significantly by species (Ryals et al., 1999). Birds may be able to protect themselves against damage from sustained sound exposures by reducing middle ear pressure, an ability that may protect ears while in flight (Ryals et al., 1999) and from injury due to pressure changes during diving (Dooling & Therrien, 2012).

Hearing loss is typically quantified in terms of threshold shift—the amount (in dB) that hearing thresholds at one or more specified frequencies are elevated, compared to their pre-exposure values, at some specific time after the noise exposure. The amount of threshold shift measured usually decreases with increasing recovery time — the amount of time that has elapsed since a noise exposure. If the threshold shift eventually returns to zero (i.e., the hearing threshold returns to the pre-exposure value), the threshold shift is called a TTS. If the threshold shift does not completely recover (the threshold remains elevated compared to the pre-exposure value), the remaining threshold shift is called a PTS. By definition, TTS is a function of the recovery time, therefore comparing the severity of noise exposures based on the amount of induced TTS can only be done if the recovery times are also considered. For example, a 20 dB TTS measured 24 hours post-exposure indicates a more hazardous exposure than one producing 20 dB of TTS measured only two minutes after exposure; if the TTS is 20 dB after 24 hours, the TTS measured after two minutes would have likely been much higher. Conversely, if 20 dB of TTS was measured after two minutes, the TTS measured after 24 hours would likely have been much smaller.

Studies in mammals have revealed that noise exposures resulting in high levels of TTS (greater than 40 dB) may also result in neural injury without any permanent hearing loss (Kujawa & Liberman, 2009; Lin et al., 2011). It is unknown if a similar effect would be observed in birds.

Hearing Loss due to Non-Impulsive Sounds

Behavioral studies of threshold shift in birds within their frequencies of best hearing (between 2 and 4 kHz) due to long-duration (30 minutes to 72 hours) continuous, non-impulsive, high-level sound exposures in air have shown that susceptibility to hearing loss varies substantially by species, even in species with similar auditory sensitivities, hearing ranges, and body size (Niemiec et al., 1994; Ryals et al., 1999; Saunders & Dooling, 1974). For example, Ryals et al. (1999) conducted the same exposure experiment on quail and budgerigars, which have very similar audiograms. A 12-hour exposure to a 2.86 kHz tone at 112 dB re 20 µPa SPL [cumulative SEL of 158 dB re 20 $\mu Pa^2 s$] resulted in a 70 dB threshold shift measured after 24 hours of recovery in quail, but a substantially lower 40 dB threshold shift measured after just 12 hours of recovery in budgerigars which recovered to within 10 dB of baseline after three days and fully recovered by one month (Ryals et al., 1999). Although not directly comparable, this SPL would be perceived as extremely loud but just under the threshold of pain for humans per the American Speech-Language-Hearing Association. Whereas the 158 dB re 20 μPa^2-s SEL tonal exposure to quail discussed above caused 20 dB of PTS (Ryals et al., 1999), a shorter (four-hour) tonal exposure to quail with similar SEL (157 dB re 20 μPa^2-s) caused 65 dB of threshold shift that fully recovered within two weeks (Niemiec et al., 1994).

Data on threshold shift in birds due to relatively short-duration sound exposures that could be used to estimate the onset of threshold shift is limited. Saunders and Dooling (1974) provide the only threshold shift growth data measured for birds. Saunders and Dooling (1974) exposed young budgerigars to four levels of continuous 1/3-octave band noise (76, 86, 96, and 106 dB re 20 µPa) centered at 2.0 kHz and measured the threshold shift at various time intervals during the 72-hour exposure. The earliest measurement found 7 dB of threshold shift after approximately 20 minutes of exposure to the 96 dB re 20 µPa SPL noise (127 dB re 20 µPa^2-s SEL). Generally, onset of TTS in other species has been considered 6 dB above measured threshold (Finneran, 2015), which accounts for natural variability in auditory thresholds. The Saunders and Dooling (1974) budgerigar data is the only bird data showing low levels of threshold shift. Because of the observed variability of threshold shift susceptibility among bird species and the relatively long duration of sound exposure in Saunders and Dooling (1974), the observed onset level cannot be assumed to represent the SEL that would cause onset of TTS for other bird species or for shorter duration exposures (i.e., a higher SEL may be required to induce threshold shift for shorter duration exposures).

Since the goal of most bird hearing studies has been to induce hair cell damage to study regeneration and recovery, exposure durations were purposely long. Studies with other non-avian species have shown that long-duration exposures tend to produce more threshold shift than short-duration exposures with the same SEL [e.g., see Finneran (2015)]. The SELs that induced TTS and PTS in these studies likely over-estimate the potential for hearing loss due to any short-duration sound of comparable SEL that a bird could encounter outside of a controlled laboratory setting. In addition, these studies were not designed to determine the exposure levels associated with the onset of any threshold shift or to determine the lowest SEL that may result in PTS.

With insufficient data to determine PTS onset for birds due to a non-impulsive exposure, data from other taxa are considered. Studies of terrestrial mammals suggest that 40 dB of threshold shift is a reasonable estimate of where PTS onset may begin [see (Southall et al., 2007)]. Similar amounts of threshold shift have been observed in some bird studies with no subsequent PTS. Of the birds studied, the budgerigars showed intermediate susceptibility to threshold shift; the budgerigars exhibited threshold shifts in the range of 40– 50 dB after 12-hour exposures to 112 dB and 118 dB re 20 µPa SPL tones at 2.86 kHz (158 – 164 dB re 20 µPa^2-s SEL), which recovered to within 10 dB of baseline after three days and fully recovered by one month (Ryals et al., 1999). These experimental SELs are a conservative estimate of the SEL above which PTS may be considered possible for birds.

All of the above studies were conducted in air. There are no studies of hearing loss to diving birds due to underwater exposures.

Hearing Loss due to Impulsive Sounds

The only measure of hearing loss in a bird due to an impulsive noise exposure was conducted by Hashino et al. (1988), in which budgerigars were exposed to the firing of a pistol with a received level of 169 dB re 20 µPa peak SPL (two gunshots per each ear); SELs were not provided. While the gunshot frequency power spectrum had its peak at 2.8 kHz, threshold shift was most extensive below 1 kHz. Threshold shift recovered at frequencies above 1 kHz, while a 24 dB PTS was sustained at frequencies below 1 kHz. Studies of hearing loss in diving birds exposed to impulsive sounds underwater do not exist.

Because there is only one study of hearing loss in birds due to an impulsive exposure, the few studies of hearing loss in birds due to exposures to non-impulsive sound are the only other avian data upon which to assess bird susceptibility to hearing loss from an impulsive sound source. Data from other taxa (U.S. Department of the Navy, 2017a) indicate that, for the same SEL, impulsive exposures are more likely to result in hearing loss than non-impulsive exposures. This is due to the high peak pressures and rapid pressure rise times associated with impulsive exposures.

F.9.1.1.3 Masking

Masking occurs when one sound, distinguished as the 'noise,' interferes with the detection or recognition of another sound. The quantitative definition of masking is the amount in decibels an auditory detection or discrimination threshold is raised in the presence of a masker (Erbe et al., 2016). As discussed in the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (Section F.1.1), masking can effectively limit the distance over which an animal can communicate and detect biologically relevant sounds. Masking only occurs in the presence of the masking noise and does not persist after the cessation of the noise.

Critical ratios are the lowest ratio of signal-to-noise at which a signal can be detected. When expressed in decibels, critical ratios can easily be calculated by subtracting the noise level (in dB re 1 μPa^2 /Hz) from the signal level (in dB re 1 μPa) at detection threshold. A signal must be received above the critical ratio at a given frequency to be detectable by an animal. Critical ratios have been determined for a variety of bird species [e.g., Dooling (1980), Noirot et al. (2011), Dooling and Popper (2000), and Crowell (2016)] and inter-species variability is evident. Some birds exhibit low critical ratios at certain vocal frequencies, perhaps indicating that hearing evolved to detect signals in noisy environments or over long distances (Dooling & Popper, 2000).

The effect of masking is to limit the distance over which a signal can be perceived. An animal may attempt to compensate in several ways, such as by increasing the source level of vocalizations (the Lombard effect), changing the frequency of vocalizations, or changing behavior (e.g., moving to another location, increase visual display). Birds have been shown to shift song frequencies in the presence of a tone at a similar frequency (Goodwin & Podos, 2013), and in continuously noisy urban habitats, populations have been shown to have altered song duration and shift to higher frequencies (Slabbekoorn & den Boer-Visser, 2006). Changes in vocalization may incur energetic costs and hinder communication with conspecifics, which, for example, could result in reduced mating opportunities. These effects are of long-term concern in constant noisy urban environments (Patricelli & Blickley, 2006) where masking conditions are prevalent.

F.9.1.1.4 Physiological Stress

Animals in the marine environment naturally experience stressors within their environment and as part of their life histories. Changing weather and ocean conditions, exposure to diseases and naturally occurring toxins, lack of prey availability, social interactions with members of the same species, nesting, and interactions with predators all contribute to stress. Anthropogenic sound-producing activities have the potential to provide additional stressors beyond those that naturally occur, as described in the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (see Section F.1.1).

Chronic stress due to disturbance may compromise the general health and reproductive success of birds (Kight et al., 2012), but a physiological stress response is not necessarily indicative of negative consequences to individual birds or to populations (Larkin et al., 1996; National Park Service, 1994). The reported behavioral and physiological responses of birds to noise exposure can fall within the range of normal adaptive responses to external stimuli, such as predation, that birds face on a regular basis. These responses can include activation of the neural and endocrine systems, causing changes such as increased blood pressure, available glucose, and blood levels of corticosteroids (Manci et al., 1988). It is possible that individuals would return to normal almost immediately after short-term or transient exposure, and the individual's metabolism and energy budget would not be affected in the long term. Studies have also shown that birds can habituate to noise following frequent exposure and cease to respond behaviorally to the noise (Larkin et al., 1996; National Park Service, 1994; Plumpton, 2006). However, the likelihood of habituation is dependent upon a number of factors, including species of bird (Bowles et al., 1991), and frequency of and proximity to exposure. Although Andersen et al. (1990) did not evaluate noise specifically, they found evidence that anthropogenic disturbance is related to changes in home ranges; for example, raptors have been shown to shift their terrestrial home range when concentrated military training activity was introduced to the area. On the other hand, cardinals nesting in areas with high levels of military training activity (including gunfire, artillery, and explosives) were observed to have similar reproductive success and stress hormone levels as cardinals in areas of low activity (Barron et al., 2012).

While physiological responses such as increased heart rate or startle response can be difficult to measure in the field, they often accompany more easily measured reactions like behavioral responses. A startle is a reflex characterized by rapid increase in heart rate, shutdown of nonessential functions, and mobilization of glucose reserves. Habituation keeps animals from expending energy and attention on harmless stimuli, but the physiological component might not habituate completely (Bowles, 1995).

A strong and consistent behavioral or physiological response is not necessarily indicative of negative consequences to individuals or to populations (Bowles, 1995; Larkin et al., 1996; National Park Service, 1994). For example, many of the reported behavioral and physiological responses to noise are within the range of normal adaptive responses to external stimuli, such as predation, that wild animals face on a regular basis. In many cases, individuals would return to homeostasis or a stable equilibrium almost immediately after exposure. The individual's overall metabolism and energy budgets would not be affected if it had time to recover before being exposed again. If the individual does not recover before being exposed again, physiological responses could be cumulative and lead to reduced fitness. However, it is also possible that an individual would have an avoidance reaction (i.e., move away from the noise source) to repeated exposure or habituate to the noise when repeatedly exposed.

Due to the limited information about acoustically induced stress responses, the Navy conservatively assumes in its effects analysis that any physiological response (e.g., hearing loss or injury) or significant behavioral response is also associated with a stress response.

F.9.1.1.5 Behavioral Reactions

Numerous studies have documented that birds and other wild animals respond to human-made noise, including aircraft overflights, weapons firing, and explosions (Larkin et al., 1996; National Park Service, 1994; Plumpton, 2006). The manner in which an animal responds to noise could depend on several factors, including life history characteristics of the species; characteristics of the noise source, sound source intensity, onset rate, distance from the noise source, presence or absence of associated visual stimuli, food and habitat availability, and previous exposure (see Section F.1.1, Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities). Researchers have documented a range of bird behavioral responses to noise, including no response, head turn, alert behavior, startle response, flying or swimming away, diving into the water, and increased vocalizations (Brown et al., 1999; Larkin et al., 1996; National Park Service, 1994; Plumpton, 2006; Pytte et al., 2003; Stalmaster & Kaiser, 1997). Some behavioral responses may be accompanied by physiological responses, such as increased heart rate or short-term changes in stress hormone levels (Partecke et al., 2006).

Behavioral responses may depend on the characteristics of the noise, and whether the noise is similar to biologically relevant sounds such as alarm calls by other birds and predator sounds. For example, European starlings (*Sturnus vulgaris*) took significantly longer to habituate to repeated bird distress calls than white noise or pure tones (Johnson et al., 1985). Starlings may have been more likely to continue to respond to the distress because it is a more biologically meaningful sound. Starlings were also more likely to habituate in winter than summer, possibly meaning that food scarcity or seasonal physiological conditions may affect intensity of behavioral response (Johnson et al., 1985).

Behavioral Reactions to Impulsive Sound Sources

Studies regarding behavioral responses by non-nesting birds to impulsive sound sources are limited. Seismic surveys had no noticeable effects on the movements or diving behavior of long-tailed ducks undergoing wing molt, a period in which flight is limited and food requirements are high (Lacroix et al., 2003). The birds may have tolerated the seismic survey noise to stay in preferred feeding areas.

Responses to aircraft sonic booms are informative of responses to single impulsive sounds. Responses to sonic booms are discussed below in Behavioral Reactions to Aircraft.

Behavioral Reactions to Sonar and Other Active Acoustic Sources

There are no studies of bird responses underwater to sonars, but the effect of pingers on fishing nets has been examined. Fewer common murres (*Uria aalge*) were entangled in gillnets when the gillnets were outfitted with 1.5 kHz pingers with a source level of 120 dB re 1 µPa; however, there was no significant reduction in rhinoceros auklet (*Cerorhinca monocerata*) bycatch in the same nets (Melvin et al., 2011; Melvin et al., 1999). It was unknown whether the pingers elicited a behavioral response by the birds or decreased prey availability.

Behavioral Reactions to Aircraft

There are multiple possible factors involved in behavioral responses to aircraft overflights, including the noise stimulus as well as the visual stimulus.

Observations of tern colonies responses to balloon overflights suggest that visual stimulus is likely to be an important component of disturbance from overflights (Brown, 1990). Although it was assumed nesting colonial waterbirds would be more likely to flush or exhibit a mob response when disturbed, observations of nesting black skimmers and nesting least, gull-billed, and common terns showed they did not modify nesting behavior in response to military fixed-wing aircraft engaged in low-altitude tactical flights and rotary-wing overflights (Hillman et al., 2015). Maximum behavioral responses by crested tern (*Sterna bergii*) to aircraft noise were observed at sound level exposures greater than 85 A-weighted decibels (dBA) re 20 µPa. However, herring gulls (*Larus argentatus*) significantly increased their aggressive interactions within the colony and their flights over the colony during overflights with received SPLs of 101–116 dBA re 20 µPa (Burger, 1981).

Raptors and wading birds have responded minimally to jet (110 dBA re 20 µPa) and propeller plane (92 dBA re 20 µPa) overflights, respectively (Ellis, 1981). Jet flights greater than 1,640 ft. (500 m) distance from raptors were observed to elicit no response (Ellis, 1981). The effects of low-altitude military training flights on wading bird colonies in Florida were estimated using colony distributions and turnover rates. There were no demonstrated effects of military activity on wading bird colony establishment or size (Black et al., 1984). Fixed-winged jet aircraft disturbance did not seem to adversely affect waterfowl observed during a study in coastal North Carolina (Conomy et al., 1998); however, harlequin ducks were observed to show increased agonistic behavior and reduced courtship behavior up to one to two hours after low-altitude military jet overflights (Goudie & Jones, 2004).

It is possible that birds could habituate and no longer exhibit behavioral responses to aircraft noise, as has been documented for some impulsive noise sources (Ellis, 1981; Russel et al., 1996) and aircraft noise (Conomy et al., 1998). Ellis (1981), found that raptors would typically exhibit a minor short-term startle response to simulated sonic booms, and no long-term effect to productivity was noted.

F.9.1.1.6 Long Term Consequences

Long term consequences to birds due to acoustic exposures are considered following the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (see Section F.1.1).

Long-term consequences due to individual behavioral reactions and short-term instances of physiological stress are especially difficult to predict because individual experience over time can create complex contingencies. It is more likely that any long-term consequences to an individual would be a result of costs accumulated over a season, year, or life stage due to multiple behavioral or stress responses resulting from exposures to multiple stressors over significant periods of time. Conversely, some birds may habituate to or become tolerant of repeated acoustic exposures over time, learning to ignore a stimulus that in the past did not accompany any overt threat. Most research on long-term consequences to birds due to acoustic exposures has focused on breeding colonies or shore habitats, and does not address the brief exposures that may be encountered during migration or foraging at sea. More research is needed to better understand the long-term consequences of human-made noise on birds, although intermittent exposures are assumed to be less likely than prolonged exposures to have lasting consequences.

F.9.1.2 Effects from Pile Driving

Noise from the installation and removal of piles has a potential to affect animals in the vicinity of the training event. Impact pile driving creates repetitive impulsive sound. An impact pile driver generally operates in the range of 36–50 blows per minute. Vibratory pile extraction creates a nearly continuous sound made up of a series of short duration rapid impulses at a much lower source level than impact pile driving. The sounds are emitted both in the air and in the water in nearshore areas where some birds forage. It is expected that most birds would exhibit avoidance behavior and leave the pile driving location. However, if prey species such as fish are killed or injured as a result of pile driving, some birds may continue to forage close to the construction area, or may be attracted to the area, and be exposed to associated noise. Behavioral responses and displacement from the area are expected to be temporary for the duration of the pile driving and extraction activities.

Impulses from the impact hammer are broadband and carry most of their energy in the lower frequencies. The underwater SPLs produced by impact pile driving during Navy activities are below the conservatively estimated injury thresholds recommended for other small animals with similar sized air cavities (sea turtles and fish; see Popper et al. (2014)). Therefore, the risk of barotrauma to any diving birds is negligible. Impulses from the impact hammer attenuate more quickly in air than in water and birds are likely to avoid the area during impact driving. Therefore, the risk of barotrauma to birds in air or at the water surface is negligible.

Pursuit divers may remain underwater for minutes, increasing the chance of underwater sound exposure. However, the short duration of driving or extracting a single pile would limit the likelihood of exposure, especially since a bird that is disturbed by pile driving while underwater may respond by swimming to the surface. Although it is not known what duration or intensity of underwater sound exposure would put a bird at risk of hearing loss, birds are less susceptible to both temporary and PTS than mammals (Saunders & Dooling, 1974). Diving birds have adaptations to protect the middle ear and tympanum from pressure changes during diving that may affect hearing (Dooling & Therrien, 2012). While some adaptions may exist to aid in underwater hearing, other adaptations to protect in-air hearing may limit aspects of underwater hearing (Hetherington, 2008). Because of these reasons, the likelihood of a diving bird experiencing an underwater exposure to impact pile driving that could affect hearing is considered low. Vibratory pile extraction sound levels are low and are not considered to pose a risk to bird hearing in air or in water.

Because diving birds may rely more on vision for foraging, there is no evidence that diving birds rely on underwater acoustic communication for foraging, and individual pile driving and extraction occurs only over a few minutes, the masking of important acoustic signals underwater by pile driving is unlikely. The potential for masking of calls in air would also likely be limited because of the short duration of individual pile driving and extraction and the likelihood that birds would avoid the area around pile driving activities.

Responses by birds to noise from pile driving would be short-term behavioral or physiological responses (e.g., alert response, startle response, and temporary increase in heart rate). Startle or alert reactions are not likely to disrupt major behavior patterns, such as migrating, breeding, feeding, and sheltering, or to result in serious injury to any birds. Some birds may be attracted to the area to forage for prey species killed or injured as a result of pile driving and be exposed to noise from pile driving temporarily. Birds may be temporarily displaced and there may be temporary increases in stress levels; however, behavior and use of habitat would return shortly after the training is complete.

F.9.2 Explosive Stressors

F.9.2.1 Effects from Explosives

F.9.2.1.1 Injury

If a bird is close to an explosive detonation, the exposure to high pressure levels and sound impulse can cause barotrauma. Barotrauma is physical injury due to a difference in pressure between an air space inside the body and the surrounding air or water. Sudden very high pressures can also cause damage at tissue interfaces due to the way pressure waves travel differently through tissues with different material properties. Damage could also occur to the structure of the ear, considered to be the body part most susceptible to pressure damage.

Detonations that occur underwater could injure, kill, or disturb diving birds, particularly pursuit divers that spend more time underwater than other foraging birds (Danil & St Leger, 2011). Studies show that birds are more susceptible to underwater explosions when they are submerged versus partially submerged on the surface. Two species of duck were exposed to explosive blasts while submerged 0.61 m and while sitting on the water surface. Onset of mortality (LD_1) was predicted to occur at an impulse exposure of 248 pascal seconds (Pa-s) (36 pounds per square inch per millisecond [psi-ms]) for birds underwater and 690 Pa-s (100 psi-ms) for birds at the water surface (Yelverton & Richmond, 1981). No injuries would be expected for birds underwater at blast pressures below 41 Pa-s (6 psi-ms) and for birds on the surface at blast pressures below 207 Pa-s (30 psi-ms) (Yelverton & Richmond, 1981). Tests of underwater explosive exposures to other taxa (fish, mammals) have shown that susceptibility to injury is related to animal mass, with smaller animals being more susceptible to injury (Yelverton & Richmond, 1981). It is reasonable to assume that this relationship would apply to birds as well. The range to these thresholds would be based on several factors including charge size, depth of the detonation, and how far the bird is beneath the water surface.

Detonations in air or at the water surface could also injure birds while either in flight or at the water surface. Experiments that exposed small, medium, and large birds to blast waves in air were conducted to determine the exposure levels that would be injurious (Damon et al., 1974). Birds were assessed for internal injuries to air sacs, organs, and vasculature, as well as injury to the auditory tympanum, but internal auditory damage was not assessed. Results indicated that peak pressure exposure of 5 psi would be expected to produce no blast injuries, 10 psi would produce slight to extensive injuries, and 20 psi would produce 50 percent mortality. These results also suggested that birds with higher mass may be less susceptible to injury. In addition to the risk of direct blast injury, exposure to an explosion in air may cause physical displacement of a bird that could be injurious. The same study examined displacement injuries to birds (Damon et al., 1974). Results indicated that impulse exposures below 5 psi-ms would not be expected to result in injuries.

One experiment was conducted with birds in flight, showing how birds can withstand relatively close exposures to in-air explosions (Damon et al., 1974). Flying pigeons were exposed to a 64-pound (lb.) net explosive weight explosion. Birds at 44–126 ft. from the blast exhibited no signs of injury, while serious injuries were sustained at ranges less than 40 ft. The no injury zone in this experiment was also for exposures less than 5 psi-ms impulse, similar to the results of the displacement injury study.

Ranges to the no injury threshold for a range of in-air explosives are shown in Table F-7.

Table F-7: Range to No Blast Injury for Birds Exposed to Aerial Explosives

Net explosive weight	***Range to 5 psi***
5 pounds (lb.)	21 feet (ft.)
10 lb.	26 ft.
100 lb.	57 ft.

Note: Ranges calculated using the methods in U.S. Department of the Navy (1975).

Another risk of explosions in air is exposure to explosive fragmentation, in which pieces of the casing of a cased explosive are ejected at supersonic speeds from the explosion. The risk of direct strike by fragmentation would decrease exponentially with distance from the explosion, as the worst case for strike at any distance is the surface area of the casing fragments, which ultimately would decrease their outward velocity under the influence of drag. It is reasonable to assume that a direct strike in air or at the water surface would be mortal. Once in water, the drag on any fragments would quickly reduce their velocity to non-hazardous levels (Swisdak & Montanaro, 1992).

The initial detonation in a series of detonations may deter birds from subsequent exposures via an avoidance response, however, birds have been observed taking interest in surface objects related to detonation events and subsequently being killed by a following detonation [Stemp, R. in Greene et al. (1985)].

F.9.2.1.2 Hearing Loss

Exposure to intense sound may result in hearing loss which persists after cessation of the noise exposure. There are no data on hearing loss in birds specifically due to explosives; therefore, the limited data on hearing loss due to impulsive sounds, apply to explosive exposures.

F.9.2.1.3 Physiological Stress

Birds naturally experience stressors within their environment and as part of their life histories. Changing weather and ocean conditions, exposure to diseases and naturally occurring toxins, lack of prey availability, social interactions with members of the same species, nesting, and interactions with predators all contribute to stress. Exposures to explosives have the potential to provide additional stressors beyond those that naturally occur, as described in the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (see Section F.1.1).

There are no data on physiological stress in birds specifically due to explosives; therefore, the limited data on physiological stress due to impulsive sounds, apply to explosive exposures.

F.9.2.1.4 Masking

Masking occurs when one sound, distinguished as the 'noise,' interferes with the detection or recognition of another sound. Exposure to explosives may result in masking. There are no data on masking in birds specifically due to explosives; therefore, the limited data on masking due to impulsive sounds, apply to explosive exposures. Due to the very brief duration of an explosive sound, any masking would be brief during an explosive activity.

F.9.2.1.5 Behavioral Reactions

Numerous studies have documented that birds and other wild animals respond to human-made noise, including aircraft overflights, weapons firing, and explosions (Larkin et al., 1996; National Park Service, 1994; Plumpton, 2006). The limited data on behavioral reactions due to impulsive sounds, apply to explosive exposures.

Because data on behavioral responses by birds to explosions is limited, information on bird responses to other impulsive sounds may be informative. Seismic surveys had no noticeable effects on the movements or diving behavior of long-tailed ducks undergoing wing molt, a period in which flight is limited and food requirements are high (Lacroix et al., 2003). The birds may have tolerated the seismic survey noise to stay in preferred feeding areas. The sensitivity of birds to disturbance may also vary during different stages of the nesting cycle. Similar noise levels may be more likely to cause nest abandonment during incubation of eggs than during brooding of chicks because birds have invested less time and energy and have a greater chance of re-nesting (Knight & Temple, 1986).

F.9.2.1.6 Long Term Consequences

Long-term consequences to birds due to explosive exposures are considered following the Conceptual Framework for Assessing Effects from Acoustic and Explosive Activities (Section F.1.1.6).

Long-term consequences to a population are determined by examining changes in the population growth rate. Physical effects that could lead to a reduction in the population growth rate include mortality or injury, which could remove animals from the reproductive pool, and permanent hearing impairment, which could affect foraging and communication. The long-term consequences due to individual behavioral reactions and short-term instances of physiological stress are especially difficult to predict because individual experience over time can create complex contingencies. It is more likely that any long-term consequences to an individual would be a result of costs accumulated over a season, year, or life stage due to multiple behavioral or stress responses resulting from exposures to multiple stressors over significant periods of time. Conversely, some birds may habituate to or become tolerant of repeated acoustic exposures over time, learning to ignore a stimulus that in the past did not accompany any overt threat. More research is needed to better understand the long-term consequences of anthropogenic stressors, although intermittent exposures to explosive noise are assumed to be less likely to have lasting consequences.

F.9.3 Energy Stressors

F.9.3.1 Effects from In-Water Electromagnetic Devices

The kinetic energy weapon referred to as a rail gun is an in-water electromagnetic device that will be tested and eventually used in training events aboard surface vessels, firing non-explosive projectiles at land- or sea-based targets. This system charges for approximately two minutes and discharges in less than a second. The duration of the firing event is extremely short (about eight milliseconds), which makes it quite unlikely that a bird would fly over at the precise moment of firing. The short duration of each firing event also means that the likelihood of affecting any animal using magnetic fields for orientation is extremely small. Further, the high magnetic field levels experienced within 80 ft. of the launcher quickly dissipate and return to background levels beyond 80 ft. The magnetic field levels outside of the 80 ft. buffer zone would be below the most stringent guidelines for humans (i.e., people with pacemakers or active implantable medical devices). Therefore, the electromagnetic effects would be temporary in nature and not expected to result in effects on organisms (U.S. Department of the Navy, 2009a), and are not analyzed further in this section.

Birds are known to use the Earth's magnetic field as a navigational cue during seasonal migrations (Akesson & Hedenstrom, 2007; Fisher, 1971; Wiltschko & Wiltschko, 2005). Birds use numerous other orientation cues to navigate in addition to magnetic fields. These include position of the sun, celestial cues, visual cues, wind direction, and scent (Akesson & Hedenstrom, 2007; Fisher, 1971; Haftorn et al., 1988; Wiltschko & Wiltschko, 2005). It is believed that birds are able to successfully navigate long distances by using a combination of these cues. A magnetite-based (magnetic mineral) receptor mechanism in the upper beak of birds provides information on position and compass direction (Wiltschko & Wiltschko, 2005). Towed in-water electromagnetic device effects on birds would only occur underwater and would only affect diving species or species on the surface in the immediate area where the device is deployed. There is no information available on how birds react to electromagnetic fields underwater.

F.9.3.2 Effects from In-Air Electromagnetic Devices

Currently, questions exist about far-field, non-thermal effects from low-power, in-air electromagnetic devices. Manville (2016) performed a literature review of this topic. Although findings are not always consistent, Manville (2016) reported that several peer-reviewed studies have shown non-thermal effects can include (1) affecting behavior by preventing birds from using their magnetic compass, which may in turn affect migration; (2) fragmenting the DNA of reproductive cells, decreasing the reproductive capacity of living organisms; (3) increasing the permeability of the blood-brain barrier; (4) other behavioral effects; (5) other molecular, cellular, and metabolic changes; and (6) increasing cancer risk.

Cucurachi et al. (2013) also performed a literature review of 113 studies and reported that (1) few field studies were performed (the majority were conducted in a laboratory setting); (2) 65 percent of the studies reported ecological effects both at high as well as low dosages (i.e., those that are compatible with real field situations, at least on land); (3) no clear dose-effect relationship could be discerned but that studies finding an effect applied higher durations of exposure and focused more on mobile phone frequency ranges; and (4) a lack of standardization and a limited number of observations limited the possibility of generalizing results from an organism to an ecosystem level.

Many bird species return to the same stopover, wintering, and breeding areas every year and often follow the exact same or very similar migration routes (U.S. Department of the Navy, 2002), and ample evidence exists that displaced birds can successfully reorient and find their way when one or more cues are removed (U.S. Department of the Navy, 2009a). For example, Haftorn et al. (1988) found that after removal from their nests and release into a different area, snow petrels (*Pagodrama nivea*) were able to successfully navigate back to their nests even when their ability to smell was removed. Furthermore, Wiltschko and Wiltschko (2005) report that in-air electromagnetic pulses administered to birds during an experimental study on orientation do not deactivate the magnetite-based receptor mechanism in the upper beak altogether but instead cause the receptors to provide altered information, which in turn causes birds to orient in different directions. However, these effects were temporary, and the ability of the birds to correctly orient themselves eventually returned. Similar results were found by a subsequent study by Wiltschko et al. (2011) on European robins (*Erithacus rubecula*) that tested the effects of exposure to specific wavelengths of visible light. Therefore, in the unlikely event that a bird is temporarily disoriented by an electromagnetic device, it is expected that it would still be able to reorient using its internal magnetic compass to aid in navigation once the stressor ceases or the bird and stressor are separated by sufficient distance. Therefore, any temporary disorientation experienced by birds from electromagnetic changes caused by training activities in the Study Area may be considered a short-term effect and would not hinder bird navigation abilities. Furthermore, other orientation cues may include position of the sun and moon, visual cues, wind direction, infrasound, and scent; these cues would not be affected by in-air electromagnetic devices.

The Environmental Assessment (EA) for the Upgraded AEGIS Combat System concluded that the rapid increase of the bird population around a newly constructed radar installation "indicates that any negative effects of the radiation zone overhead have been negligible." Another study on the effects of extremely low-frequency in-air electromagnetic fields on breeding and migrating birds around the Navy's extra-low-frequency communication system antenna in Wisconsin found no evidence that bird distribution or abundance was affected by in-air electromagnetic fields produced by the antenna. In addition, radars, including X-band systems, are frequently used to track bird movements as it has been demonstrated that they do not affect bird behavior. Moreover, previous studies have consistently determined that the chances that a bird will move in the same direction and at the same speed as a constant beam of electromagnetic radiation (e.g., while an in-air electromagnetic device tracks a target), and therefore be exposed to radiation that could cause thermal damage, are extremely small.

California least terns could be exposed to intermittent in-air electromagnetic stressors in nearshore areas where training activities occur. If present in the open water areas where training activities involving in-air electromagnetic stressors occur, Hawaiian petrel, short-tailed albatross, marbled murrelet, Newell's shearwater, or band-rumped storm-petrel could be temporarily disturbed while foraging or migrating.

Given (1) the information provided above; (2) the dispersed nature of Navy testing and training activities at sea; and (3) the relatively low-level and dispersed use of these systems at sea, the following conclusions are reached:

- The chance that in-air electromagnetic devices would cause thermal damage to an individual bird is extremely low;
- It is possible, although unlikely, that some bird individuals would be exposed to levels of electromagnetic radiation that would cause discomfort, in which case they would likely avoid the immediate vicinity of testing and training activities;
- The strength of any avoidance response would decrease with increasing distance from the in-air electromagnetic device; and
- No long-term or population-level effects would occur.

F.9.4 Physical Disturbance and Strike Stressors

F.9.4.1 Effects from Vessels

Direct collisions with most Navy vessels (or a vessel's rigging, cables, poles, or masts) are unlikely but may occur, especially at night. Many bird species are attracted to artificial lighting, particularly Procellariiformes. Newell's shearwater and Hawaiian petrel fledglings are particularly attracted to light, which can cause exhaustion and increase potential for collision with land-based structures (Reed et al., 1985). Lighting on boats and vessels has also contributed to bird fatalities in open-ocean environments when birds are attracted to these lights, usually in inclement weather conditions (Merkel & Johansen, 2011). Birds can become disoriented at night in the presence of artificial light (Favero et al., 2011; Hamilton, 1958; Hyrenbach, 2001, 2006), and lighting on vessels may attract some birds, increasing the potential for harmful encounters. Other effects would be the visual and behavioral disturbance from a vessel. Birds respond to moving vessels in various ways. Some birds, including certain species of gulls, storm petrels, and albatrosses, commonly follow vessels (Favero et al., 2011; Hyrenbach, 2001, 2006); while other species such as plovers, curlews, frigatebirds, and sooty terns seem to avoid vessels (Borberg et al., 2005; Hyrenbach, 2006). There could be a slightly increased risk of effects during the winter, or fall/spring migrations when migratory birds use celestial clues during night time flight and are concentrated in coastal areas. However, despite this concentration, most birds would still be able to avoid collision with a vessel. Vessel movements could elicit short-term behavioral or physiological responses (e.g., alert response, startle response, fleeing the immediate area, temporary increase in heart rate).

Navy aircraft carriers, surface combatant vessels, and amphibious warfare ships are minimally lighted for tactical purposes. For vessels of this type there are two white lights that shine forward and one that shines aft; these lights must be visible for at least 6 NM. A single red and a single green light are located on the port and starboard sides of vessels, respectively. These lights are visible for a minimum of 3 NM. Solid white lighting appears more problematic for birds, especially nocturnal migrants (Gehring et al., 2009; Poot et al., 2008). Navy vessel lights are mostly solid, but sometimes may not appear solid because of the constant movement of the vessel (wave action), making vessel lighting potentially less problematic for birds in some situations.

While some potential exists for birds to be struck by vessels as they are foraging, resting, or flying near the water surface, most birds would be expected to see or hear an oncoming vessel and to fly or swim away to avoid a potentially harmful encounter. Injury or mortality could occur if a bird were struck, but most bird encounters with vessels would be expected to result in a brief behavioral and physiological response as described above. It should be noted that such responses involve at the least a temporary displacement of birds from foraging areas, resulting in energetic costs to the birds (Velando & Munilla, 2011). Birds would be expected to return and resume foraging soon after the vessel passed through the area, or to forage elsewhere, and the fitness of individual birds would probably not be compromised.

Other harmful bird-vessel interactions are commonly associated with commercial fishing vessels because birds are attracted to concentrated food sources around these vessels (Dietrich & Melvin, 2004; Melvin & Parrish, 2001). However, concentrated food sources are not associated with Navy vessels, so birds following Navy vessels would be very unlikely.

Amphibious vessel movements could elicit short-term behavioral or physiological responses such as alert response, startle response, cessation of feeding, fleeing the immediate area, nest abandonment, and a temporary increase in heart rate. There could be a slightly increased risk of effects during the winter, or fall/spring migrations and during nesting season when migratory birds are concentrated in coastal areas where amphibious vessels have the potential to disturb nesting or foraging shorebirds such as the ESA-listed California least tern. The general health of individual birds would not be compromised, unless a direct strike occurred. However, it is highly unlikely that a bird would be struck in this scenario because most foraging shorebirds in the vicinity of the approaching amphibious vessel would likely be dispersed by the noise of its approach before it could come close enough to strike a bird (Section 3.9.3.4.1, Effects from Vessels and In-Water Devices).

F.9.5 Entanglement Stressors

F.9.5.1 Effects from Decelerators/Parachutes

If the decelerator/parachute and its lines sink to the seafloor in an area where the bottom is calm, it would remain there undisturbed. Over time, it may become covered by sediment in most areas or colonized by attaching and encrusting organisms, which would further stabilize the material and reduce the potential for reintroduction as an entanglement risk. If bottom currents are present, the canopy may billow and pose an entanglement threat to birds that feed in benthic habitats. Bottom-feeding birds tend to forage in nearshore areas rather than offshore, where these decelerators/parachutes are used; therefore, birds are not likely to encounter decelerators/parachutes once they reach the seafloor. The potential for a bird to encounter an expended decelerator/parachute at the surface or in the water column is extremely low, it is even less probable at the seafloor given the general improbability of a bird being near the deployed decelerator/parachute as well as the general behavior of birds. Depending on how quickly the decelerator/parachute may degrade, the risk may increase with time if the decelerator/parachute remains intact. Factors that may influence degradation times include exposure to ultraviolet radiation and the extent of physical damage of the decelerator/parachute on the water's surface, as well as water temperature and sinking depth.

F.9.6 Ingestion Stressors

F.9.6.1 Effects from Military Expended Materials Other Than Munitions

The analysis in this section includes the potential ingestion of military expended materials other than munitions, all of which are expended away from nearshore habitats and close to the water surface. Tables 3.0-20, 3.0-21, 3.0-24, and 3.0-26describe the annual quantities and locations where these materials would be generated by training and testing activities under Alternatives 1 and 2. Appendix A (Navy Activity Descriptions) provides more specific information on the activities that may result in ingestion stressors, and the typical locations where these activities occur.

While it has been widely documented that a wide range of marine organisms (including zooplankton, baleen whales, and seabirds) will ingest plastic, the mechanism that causes these organisms to do so was discovered only recently (Savoca, 2016; Savoca et al., 2016). Procellariiformes, or tube-nosed seabirds (e.g., albatrosses, shearwaters and petrels) utilize a highly developed sense of smell to find food that is patchily distributed in offshore and open ocean environments. Specifically, these birds are attracted to dimethyl sulfide, which is produced when the cell walls of algae are damaged (e.g., when marine herbivores such as krill eat it), thereby alerting the seabirds that food (e.g., krill) are nearby. Through a literature review, Savoca et al. (2016) demonstrated that seabirds that utilize dimethyl sulfide as a foraging cue consumed plastic nearly six times more frequently than species that were not attracted to dimethyl sulfide. Savoca et al. (2016) also performed field studies that confirmed that algae growing on three of the most common types of plastic debris (polypropylene and low- and high-density polyethylene) can produce dimethyl sulfide within three weeks at concentrations at least four orders of magnitude above the behavioral detection threshold for Antarctic prions (*Pachyptila desolata*), thereby creating an "olfactory trap."

Birds could potentially ingest expended materials other than munitions used by the Navy during training and testing activities within the Study Area. The Navy expends the following types of materials that could become ingestion stressors for birds during training and testing in the Study Area: missile components, target fragments, chaff and flare endcaps/pistons, and decelerators/parachutes.

Ingestion of expended materials by birds could occur in all large marine ecosystems and open ocean areas and would occur either at the surface or just below the surface portion of the water column, depending on the size and buoyancy of the expended object and the feeding behavior of the birds. Floating material of ingestible size could be eaten by birds that feed at or near the water surface, while materials that sink pose a potential risk to diving birds that feed just below the water's surface (Titmus & Hyrenbach, 2011). Some items, such as decelerators/parachutes or sonobuoys are too large to be ingested and will not be discussed further. Also, decelerators/parachutes sink rapidly to the seafloor.

Physiological effects on birds from ingestion include blocked digestive tracts and subsequent food passage, blockage of digestive enzymes, lowered steroid hormone levels, delayed ovulation (egg maturation), reproductive failure, nutrient dilution (nonnutritive debris displaces nutritious food in the gut), exposure to indirect effects from harmful chemicals found in and on the plastic material, and altered appetite satiation (the sensation of feeling full), which can lead to starvation (Azzarello & Van Vleet, 1987). While ingestion of marine debris has been linked to bird mortalities, sublethal effects are more common (Moser & Lee, 1992).

Many species of seabirds are known to ingest floating plastic debris and other foreign matter while feeding on the surface of the ocean (Auman et al., 1997; Yamashita et al., 2011). Evidence indicates that physical and toxicological effects from plastic ingestion by seabirds are widespread among species and pervasive in terms of the number of individuals affected, and that effects are increasing (Kain et al., 2016; Wilcox et al., 2015). For example, 21 of 38 seabird species (55 percent) collected off the coast of North Carolina from 1975 to 1989 contained plastic particles (Moser & Lee, 1992). The mean particle sizes of ingested plastic were positively correlated with the birds' size though the mean mass of plastic found in the stomachs and gizzards of 21 species was below 3 grams. In Hawaii, the proportion of necropsied Newell's shearwaters and wedge-tailed shearwaters (*Ardenna pacifica*) that were found to have ingested plastic more than doubled from 2007 to 2014 (Kain et al., 2016). The number of plastic particles found in the stomachs of northern fulmars in the North Sea increased by two-to-three-fold from the mid-1980s to mid-1990s and has remained at about 30 particles per bird since then. Since the 1980s, concentrations of industrial plastics in the ocean waters and their consumption by fulmars has decreased by about 75 percent, while the abundance of user plastics and their consumption has shown no obvious trend (van Franeker & Law, 2015). Some seabirds have used plastic and other marine debris for nest building which may lead to ingestion of that debris (Votier et al., 2011). Indirect ingestion of plastic also occurs from consuming prey (such as fishes) that ingest plastic.

Plastic is often mistaken for prey, and the incidence of plastic ingestion appears to be related to a bird's feeding mode and diet (Henry et al., 2011; Provencher et al., 2014). Seabirds that feed by pursuit-diving, surface-seizing, and dipping tend to ingest plastic, while those that feed by plunging or piracy typically do not ingest plastic (Azzarello & Van Vleet, 1987; Provencher et al., 2014). Birds of the order Procellariiformes, which include petrels, shearwaters, and albatrosses, tend to accumulate more plastic than other species (Azzarello & Van Vleet, 1987; Moser & Lee, 1992; Pierce et al., 2004; Provencher et al., 2014). Some birds, including gulls and terns, commonly regurgitate indigestible parts of their food items such as shell and fish bones. However, the structure of the digestive systems of most Procellariiformes makes it difficult to regurgitate solid material such as plastic (Azzarello & Van Vleet, 1987; Moser & Lee, 1992; Pierce et al., 2004). Two species of albatross (*Diomedeidae*) have also been reported to ingest plastic while feeding at sea. While such studies have not conclusively shown that plastic ingestion is a significant source of direct mortality, it may be a contributing factor to other causes of albatross mortality (Naughton et al., 2007).

As summarized by Pierce et al. (2004), Auman et al. (1997) and Azzarello and Van Vleet (1987) documented consequences of plastic ingestion by seabirds include blockage of the intestines and ulceration of the stomach, reduction in the functional volume of the gizzard leading to a reduction of digestive capability, and distention of the gizzard leading to a reduction in hunger. Dehydration has also been documented in seabirds that have ingested plastic (Sievert & Sileo, 1993). Studies have found negative correlations between body weight and plastic load, as well as between body fat (a measure of energy reserves) and the number of pieces of plastic in a seabird's stomach (Auman et al., 1997; Ryan, 1987; Sievert & Sileo, 1993). Other possible concerns that have been identified include toxic plastic additives and toxic contaminants that could be adsorbed to the plastic from ambient seawater. Pierce et al. (2004) described two cases where plastic ingestion caused seabird mortality from starvation. The examination of a deceased adult northern gannet revealed that a 1.5 in. diameter plastic bottle cap lodged in its gizzard blocked the passage of food into the small intestine, which resulted in its death from starvation. Northern gannets are substantially larger, and dive deeper than the ESA-listed birds in the Study Area. Also, since gannets typically utilize flotsam in nest building (Votier et al., 2011), they may be more susceptible to ingesting marine debris than other species as it gathers that material. Dissection of an adult greater shearwater's gizzard revealed that a 1.5 by 0.5 in. fragment of plastic blocked the passage of food in the digestive system, which also resulted in death from starvation.

Species such as storm-petrels, albatrosses, shearwaters, fulmars, and noddies that forage by picking prey from the surface may have a greater potential to ingest any floating plastic debris (Donnelly-Greenan et al., 2014). Ingestion of plastic military expended material by any species from the taxonomic groups found within the Study Area has the potential to affect individual birds. The risk of plastic ingestion and impaction in chicks of many species of seabirds may be different from the risks to adults. Albatross chicks appear to be at greater risk than adults, because of their high rates of ingestion and apparent low frequency of regurgitative casting of indigestible material. Hyrenbach et al. (2015) demonstrated that almost 100 percent of chicks of black-footed and Laysan albatrosses breeding in the Northwestern Hawaiian Islands ingest plastics during the pre-fledging period when they are dependent upon food brought to the breeding colony by parents. Floating plastic items are ingested by adult albatrosses and regurgitated to chicks along with normal food items. Negative effects of plastic ingestion may result from impaction of the upper gastrointestinal tract and interference with passage of food through the digestive system, contributing to reduced resistance to disease and lowered post-fledging survival. Significant correlations between plastic loads and body condition or growth rates, were not found, however (Hyrenbach et al., 2015). Flesh-footed shearwater (*Puffinus carnipes*) fledglings in eastern Australia have been found to contain relatively large amounts of plastics, which is correlated with poor body condition and tissue contaminant loads (Lavers et al., 2014).

The distribution of floating expended items would be irregular in both space and time, as training and testing activities do not occur in the same place each time. The random distribution of items across the large Study Area yields very low probabilities that seabirds will encounter a floating item. However, when a seabird does encounter a floating item of ingestible size, an ingestion risk may exist. Although most military expended material components are expected to sink to the seafloor and spend limited periods within the water column, some items remain buoyant for an extended period. Expended training and testing material, such as missile components or target fragments that float, may be encountered by seabirds in the waters of the Study Area, increasing the potential for ingestion of smaller components. Ocean currents concentrate plastic debris, making seabirds that feed along frontal zones more susceptible (Azzarello & Van Vleet, 1987). While some seabird ingestion of expended materials could occur, these factors indicate that a small number of birds would be affected and that population level effects would not be expected.

Target-Related Materials

As described in Section 3.0.3.3.6.3 (Military Expended Materials), at-sea targets are usually remotely operated airborne, surface, or subsurface traveling units, most of which are designed to be recovered for reuse. However, if they are used during activities that use high explosives then they may result in fragments. Expendable targets that may result in fragments would include air-launched decoys, surface targets (e.g., marine markers, paraflares, cardboard boxes, and 10 ft. diameter red balloons), and mine shapes. Most target fragments would sink quickly to the seafloor. Floating material, such as Styrofoam, may be lost from target boats and remain at the surface for some time. Only targets that may result in smaller fragments that do not immediately sink are included in the analyses of ingestion potential.

There are additional types of targets discussed previously, but only surface targets, subsurface targets, air targets, Sinking Exercise ship hulks, and mine shapes would be expected to result in fragments when high-explosive munitions are used.

Chaff

As described in Section 3.0.3.3.6.3 (Military Expended Materials), large areas of air space and open water within the Study Area would be exposed to chaff at very low concentrations. This same section also provides a general discussion of chaff as an ingestion stressor and concludes that chaff poses little risk to organisms, except at concentrations substantially higher than those that could reasonably occur from military training. Additional information is provided below.

It is unlikely that chaff would be selectively ingested (U.S. Department of the Air Force, 1997). Ingestion of chaff fibers is not expected to cause physical damage to a bird's digestive tract based on the fibers' small size (ranging in lengths of 0.25 to 3 in. with a diameter of about 40 micrometers) and flexible nature, as well as the small quantity that could reasonably be ingested. In addition, concentrations of chaff fibers that could reasonably be ingested are not expected to be toxic to seabirds. Scheuhammer (1987) reviewed the metabolism and toxicology of aluminum in birds and mammals and found that intestinal adsorption of orally ingested aluminum salts was very poor, and the small amount adsorbed was almost completely removed from the body by excretion. Dietary aluminum normally has minor effects on healthy birds and mammals, and often high concentrations (greater than 1,000 milligrams per kilogram) are needed to induce effects such as impaired bone development, reduced growth, and anemia (U.S. Department of the Navy, 1999). A bird weighing 2.2 lb. would need to ingest more than 83,000 chaff fibers per day to receive a daily aluminum dose equal to 1,000 per kilogram; this analysis was based on chaff consisting of 40 percent aluminum by weight and a 5 ounce chaff canister containing 5 million fibers. As an example, an adult herring gull weighs about 1.8–2.7 lb. (Cornell Lab of Ornithology, 2009). It is highly unlikely that a bird would ingest a toxic dose of chaff based on the anticipated environmental concentration of chaff (i.e., 1.8 fibers per square foot for an unrealistic, worst-case scenario of 360 chaff cartridges simultaneously released at a single drop point).

Flares

A general discussion of flares as an ingestion stressor is presented in Section 3.0.3.3.4.2 (Military Expended Materials). Ingestion of flare compression pads or pistons 1.3 in. in diameter and 0.13 in. thick (U.S. Department of the Air Force, 1997) by birds may result in gastrointestinal obstruction or reproductive complications. Based on the information presented above, if a seabird were to ingest a compression pads or pistons, the response would vary based on the species and individual bird. The responses could range from none, to sublethal (reduced energy reserves), to lethal (digestive tract blockage leading to starvation). Ingestion of compression pads or pistons by species that regularly regurgitate indigestible items would likely have no adverse effects. However, compression pads or pistons are similar in size to those plastic pieces described above that caused digestive tract blockages and eventual starvation. Therefore, ingestion of compression pads or pistons could be lethal to some individual seabirds. Species with small gizzards and anatomical constrictions that make it difficult to regurgitate solid material would likely be most susceptible to blockage (such as Procellariiformes). Based on available information, it is not possible to accurately estimate actual ingestion rates or responses of individual birds.

F.9.7 Secondary Stressors

This section analyzes potential effects on birds exposed to stressors indirectly through effects on habitat and prey availability.

F.9.7.1 Effects on Habitat

The potential of water, air quality, and abiotic habitat stressors associated with training and testing activities to indirectly affect birds, as a secondary stressor, was analyzed. The assessment of potential water, air quality, and abiotic habitat stressors is discussed in previous sections in this Draft EIS/OEIS (Section 3.1, Air Quality; and Section 3.2, Sediments and Water Quality). These analyses address specific activities in local environments that may affect bird habitats. At-sea activities that may affect water and air include general emissions, and at-sea activities that may affect habitats include explosives and physical disturbance and strike.

As noted in Section 3.1 (Air Quality), and Section 3.2 (Sediments and Water Quality), implementation of the No Action Alternative, Alternative 1, or Alternative 2 would minimally affect sediments, water, air quality, or habitats, and therefore would not indirectly affect seabirds as secondary stressors. Furthermore, any physical effects on seabird habitats would be temporary and localized because training and testing activities would occur infrequently. These activities would not be expected to adversely affect seabirds or seabird habitats.

Indirect effects on sediments, water or air quality under Alternative 1 or Alternative 2 would have no effect on ESA-listed bird species due to: (1) the temporary nature of effects on sediments, water, or air quality, (2) the distribution of temporary sediments, water, or air quality effects, (3) the wide distribution of birds in the Study Area, and (4) the dispersed spatial and temporal nature of the training and testing activities that may have temporary sediments, water, or air quality effects. No long-term or population-level effects are expected.

Pursuant to the ESA, secondary effects on habitat during training or testing activities as described under Alternative 1 and Alternative 2 may affect least terns, Hawaiian petrels, short-tailed albatrosses, marbled murrelets, Newell's shearwaters, and band-rumped storm petrels. The Navy has consulted with the USFWS as required by section 7(a)(2) of the ESA.

F.9.7.2 Effects on Prey Availability

As noted in Section 3.4 (Invertebrates) and Section 3.5 (Fishes), implementation of the No Action Alternative, Alternative 1, or Alternative 2 would not adversely affect populations of invertebrate or fish prey resources (e.g., crustaceans, bivalves, worms, sand lance, herring, etc.) of birds and therefore would not indirectly affect birds as secondary stressors. Any effects on seabird prey resources would be temporary and localized. Furthermore, as discussed above, these activities are expected to have minimal effects on bird habitats. Additional detail is provided below.

As discussed in Section 3.4.3.7 (Secondary Stressors), effects on invertebrate prey availability resulting from explosives, explosives byproducts, unexploded munitions, metals, and chemicals would likely be negligible overall and population-level effects on marine invertebrates are not expected. Because individuals of many invertebrate taxa prey on other invertebrates, mortality resulting from explosions or exposure to metals or chemical materials would reduce the number of invertebrate prey items available. A few species prey upon fish, and explosions and exposure to metals and chemical materials could result in a minor reduction in the number of fish available. However, the effect is expected to be small and discountable. Any vertebrate or invertebrate animal killed or significantly impaired by Navy activities could potentially represent an increase in food availability for scavenging invertebrates. None of the effects described above would likely be detectable at the population or subpopulation level.

As noted in Section 3.6.3.7.2 (Fishes, Effects on Prey Availability), prey species might exhibit a strong startle reaction to detonations that might include swimming to the surface or scattering away from the source. This startle and flight response is the most common secondary defense among animals (Hanlon & Messenger, 1996). The sound from underwater explosions might induce startle reactions and temporary dispersal of schooling fishes if they are within close proximity to an explosion (Popper et al., 2014; Wright, 1982), which in turn could make them more visible to predators (Kastelein et al., 2008). The abundances of fish and invertebrate prey species near the detonation point could be diminished for a short period of time before being repopulated by animals from adjacent waters. Alternatively, any prey species that would be directly injured or killed by the blast could draw in scavengers from the surrounding waters that would feed on those organisms, who in turn could be susceptible to becoming directly injured or killed by subsequent explosions. Any of these scenarios would be temporary, only occurring during activities involving explosives, and no lasting effect on prey availability or the food web would be expected. Indirect effects of underwater detonations and high explosive munitions use under the Proposed Action would not result in a decrease in the quantity or quality of fish populations in the Study Area.

Based on Sections 3.4 (Invertebrates) and 3.6 (Fishes), project-related stressors would not affect populations of invertebrates and fishes that support birds in the Study Area. Therefore, no secondary effects associated with prey availability are expected. Furthermore, the Navy will implement mitigation (e.g., not conducting gunnery activities within a specified distance of shallow-water coral reefs) to avoid potential effects from explosives and physical disturbance and strike stressors on seafloor resources in mitigation areas throughout the Study Area (see Sections 5.7.1, Shallow-Water Coral Reef and Precious Coral Bed Mitgation Areas; and Section 5.7.2, Artificial Reef, Hard Bottom Substrate, and Shipwreck Mitigation Areas). This mitigation will consequently help avoid potential effects on bird prey that inhabits shallow-water coral reefs, live hard bottom, precious coral beds, artificial reefs, and shipwrecks.

Pursuant to the ESA, secondary effects on prey availability during training or testing activities as described under Alternative 1 and Alternative 2 may affect least terns, Hawaiian petrels, short-tailed albatrosses, marbled murrelets, Newell's shearwaters, and band-rumped storm petrels. The Navy has consulted with the USFWS as required by section 7(a)(2) of the ESA.

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