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EXECUTIVE SUMMARY

An earlier scientific research program on the potential effects of Surveillance Towed Array Sensor System-Low Frequency Active (SURTASS-LFA) sonar on marine mammals (1997 to 1998 Low Frequency Sound Scientific Research Program [LFS SRP]) focused on baleen whale species that are known to produce sounds in the low-frequency band (<1000 Hz) and likely have optimal hearing in the primary low-frequency band in which this sonar system operates. Recent observations based on laboratory and field studies, as well as anecdotal observations of free-ranging animals, suggest that at least some species of beaked whales and porpoises may be, in general, more behaviorally responsive to sounds like those from anthropogenic and biological sources than expected compared to other marine mammals. This general conclusion formed the motivation to consider potential beaked whale and harbor porpoise responses to SURTASS-LFA sonar, even though they do not produce sounds in and are not known to have optimal hearing in the fundamental frequency band of SURTASS-LFA sonar. Therefore, in coordination with NMFS, the U.S. Navy initiated a process to assess the potential for these cetaceans to detect and behaviorally respond to operational SURTASS-LFA sonar systems. The U.S. Navy supported a Scientific Advisory Group (SAG) of independent subject matter experts in marine acoustics and marine mammal biology, hearing, and behavioral sciences to compile an assessment of the available information regarding potential effects of SURTASS-LFA sonar on beaked whales and harbor porpoises, and to derive a strategic and iterative research approach that could be used to obtain additional information.

The SAG considered the available information on SURTASS-LFA sonar system characteristics, including harmonics produced by this system, and LFA mission areas in relation to what is known about beaked whale and porpoise distributions, life histories, hearing, and behavioral responses to sound. Each of these taxa includes multiple species. They are considered collectively here because there is some scientific information suggesting that at least some individual species are particularly sensitive to anthropogenic noise and there is a lack of evidence that this sensitivity does not extend to other species in each taxa.

Clearly there are some major information gaps regarding the SAG's efforts to make an assessment, but the SAG reached a number of conclusions using the best available information. Broadly speaking, the SAG concluded that the available data suggest that the potential for adverse effects from SURTASS-LFA sonar on beaked whales and porpoises appears limited. However, the SAG concluded that there are a number of research questions that need to be addressed to verify this conclusion and gave several specific recommendations, in a phased approach, to address the most relevant questions. It is important to note that the SAG did not evaluate the importance of this issue relative to other U.S. Navy or NMFS

information-needs regarding the potential effects of noise on marine mammals, including those from other active U.S. Navy acoustic sources.

The SAG concluded that the potential effects of SURTASS-LFA sonar on species within these two odontocete taxa will depend largely on the spectral properties of the transmissions relative to a species' hearing sensitivity, the species' relative responsiveness to underwater sound, and the spatial overlap between SURTASS-LFA sonar mission areas and the species' distribution. While there are limited data on low-frequency hearing of species in these two taxa, the available information suggests that the fundamental frequencies of SURTASS-LFA sonar (rather than harmonics) would be the most audible aspects of the signal. Any harmonics would likely be audible over limited ranges (less than a few kilometers), based on the poor low-frequency hearing of odontocete cetaceans and the relatively low source levels of the harmonics compared to the fundamental frequency. In terms of the current mission area overlap of SURTASS-LFA sonar with these two taxa, this overlap appears to be generally greater for the more pelagic beaked whales than for the more coastal porpoises, although clearly there are species differences in relative distribution within each taxa. The SAG developed a strategic, iterative, parallel research approach for beaked whales (primarily involving field work with existing methods) and porpoises (primarily involving laboratory studies with existing methods) that could be implemented to address specific information gaps, if deemed necessary.

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1 OVERVIEW AND INTRODUCTION

The U.S. Navy supports and conducts a variety of research and monitoring activities to better understand the potential effects of sound on marine mammals during routine training, testing and military operations. While many of the present research efforts relate to the potential effects of mid-frequency active tactical sonars (~ 3 to 7 kHz), considerable effort and interest has also included low-frequency sonar, specifically the U.S. Navy's Surveillance Towed Array Sensor System-Low Frequency Active (SURTASS-LFA) sonar (100 to 500 Hz band). Most of the initial research effort on potential SURTASS-LFA sonar effects understandably focused on baleen whale species because they are known to produce, and likely rely, on low-frequency sound for critical life functions. However, certain odontocete species, including several species in the beaked whale and porpoise taxa, appear to be particularly responsive to a variety of different sounds and conditions (see: Southall *et al*. 2007; Tyack *et al*. 2011; Kastelein *et al*. 2012). This observation of an unexpected sensitivity to anthropogenic noise relative to other marine mammal species comes primarily from observations of previous marine mammal stranding events and a limited number of field and laboratory measurements of behavioral responses of a few individual species (*e.g.*, Cuvier's beaked whale [*Ziphius cavirostris*], Blainville's beaked whale [*Mesoplodon densirostris*], and harbor porpoise [*Phocoena phocoena*]). Whether this apparent generalized sensitivity to some sound types extends to other sound types and other porpoise and beaked whale species is unknown. However, it is impractical to obtain relevant data for all species of beaked whales and porpoises or to forestall decisions until they are obtained. Any potential effects should be assessed relative to either direct information available for that species, available data and observations for representative species in each taxa, or extrapolations of information from other species groups where relevant (typically more so regarding hearing effects vice behavioral ones). While many of the sound sources investigated in this regard transmit mid- and high-frequency sounds (defined as 1 to 10 kHz and >10 kHz, respectively), the hearing capabilities and behavioral sensitivity of at least some of these species appear sufficiently broad and general in nature to question whether these odontocete species can even detect, and thus respond to, SURTASS-LFA sonar sources. If it is shown that beaked whales and harbor porpoises can detect and respond to SURTASS-LFA sonar, it follows that an evaluation into the extent to which these responses may pose a potential risk to either individual fitness or, ultimately, population trends and viability, should be initiated.

During the U.S. Navy's application process for the new five-year Rule for the operation of SURTASS-LFA sonar (2012 to 2017), discussions with the National Marine Fisheries Service (NMFS) identified the need for data to better assess potential effects of SURTASS-LFA sonar on harbor porpoises and beaked whales. In its Final Rule for SURTASS-LFA sonar, NMFS called for the formation of a Scientific Advisory Group (SAG) to consider various scientific and monitoring tools to gather more information and to make specific recommendations about the feasibility, efficacy, and anticipated significance of proposed research projects. This process is a requirement of the Final Rule under the Marine Mammal Protection Act (MMPA) for SURTASS LFA sonar operations. The U.S. Navy acted accordingly and formed the SAG, which consisted of subject matter experts in marine acoustics, bioacoustics, behavioral response studies, and the biology/behavior of beaked whales and porpoises (specifically harbor porpoise, for which more is known). The U.S. Navy developed the terms of reference (TOR) for the SAG (see Appendix I) and directed the SAG to complete its review and assessment of the issues identified. Similarly, this report will be considered by the U.S. Navy in consultation with NMFS with regard to any potential future research or monitoring efforts deemed appropriate.

The focus of the SAG was, as directed, to consider behavioral effects of the SURTASS-LFA and SURTASS CLFA (compact low frequency active) sonar systems on harbor porpoises and beaked whales (for exact wording, see the TOR in Appendix I). The SAG was not asked to consider all possible effects of these sonar systems on odontocetes and did not attempt to place the relative importance of these issues into an overall broader context of ongoing and needed research on the effects of U.S. Navy sound-generating activities on marine mammals.

The SAG participated in several coordinating conference calls leading up to a two-day meeting (13 to 14 March 2013). That meeting was followed by subsequent consideration of additional information regarding the harmonic structure of SURTASS-LFA sonar signals. This report represents the results of the SAG meeting and subsequent discussions, accounting for comments from an executive oversight group (EOG), which included representatives from the National Marine Fisheries Service (NMFS), U.S. Navy, as well as comments from the Marine Mammal Commission (MMC). This SAG report details the findings of the group and is deemed an independent scientific assessment of a potential strategic research and monitoring approach, specifically considering the potential for harbor porpoises and beaked whales to detect and behaviorally respond to SURTASS-LFA sonar. Other potential effects, such as auditory masking or physiological stress effects, were not considered by the SAG and are not explored herein. Rather, the questions posed in the TOR were considered and an assessment of relevant issues related to potential effects that could be addressed with a targeted, step-wise research approach was provided. All of the sound transmissions associated with the operation of the LFA and CLFA sonar sources were discussed. While there are some slight differences in these systems (discussed below), they are collectively referred to as SURTASS-LFA sources in this report. However, we also considered SURTASS-LFA vessel noise and the active high-frequency marine mammal monitoring (HF/M3) sonar system used aboard SURTASS LFA vessels to detect animals in the vicinity of active source operations. The vessels that deploy and operate the SURTASS-LFA sonar system also generate propulsion noises similar to those from other ocean-going vessels and those sounds would need to be considered in any cumulative assessment of potential effects of SURTASS-LFA sonar routine training, testing and military operations. The HF/M3 sonar system is similar in some regards to many other high-frequency active sonar systems commonly deployed for mapping, imaging, and mitigation. Sounds from these high-frequency systems may be audible to mid- and high-frequency specialized odontocetes and their potential effects should be considered. However, this was outside the scope of the present report, which focuses solely on behavioral responses of beaked whales and harbor porpoises to SURTASS-LFA sound sources.

The SAG report describes:

1. Basic information on the unclassified operating characteristics of the SURTASS-LFA sonar system;
2. The best available information on the life history, hearing, and behavioral reactions of beaked whales and porpoises to low-frequency sounds (defined as <1000 Hz);
3. Broad-scale assessment of potential spatial overlap between SURTASS-LFA sonar operations and the general distribution of beaked whales and porpoises;
4. Previous research approaches to assess potential effects of SURTASS-LFA sonar systems on baleen whales;
5. A potential, phased-research approach;
6. Key questions, known or evolving methodologies, cost/feasibility, and cost/benefit, assessment of specific research approaches; and
7. A summary of SAG observations and conclusions.

2 SURTASS-LFA SONAR SYSTEM SOURCE DESCRIPTION AND OPERATING PARAMETERS, INCLUDING MISSION AREAS

The SURTASS-LFA sound source is a vertically oriented line array (VLA) of 18 projector elements, each with a potential source level (SL) of 215 dB re 1 μPa @ 1 m (Figure 1). However, it is important to note that with sonar arrays there exists a "near-field" region and a far-field region. The "near-field" region is located close to the VLA and is where the sonar output beam is still forming. The "far-field" region exists at greater ranges from the VLA and is where the output from the VLA is fully formed (DoN 2001, Appendix B, Page B-7). The LFA sonar beam is formed by equally spacing the projectors at a distance of about one-half the acoustic wavelength of the sound being transmitted. When each projector is turned on at the same time (with the same phase signal and using the same power level and frequency), the outputs from the projectors combine to form the desired narrow vertical beam. However this beam is not fully formed until it enters the "far-field," which in the case of this sonar system, is hundreds of meters away from the VLA. What is physically occurring is that the levels from all of the individual projectors will only finally add coherently together at the same power level and phase at a point where the distance from each projector to that point is approximately the same. Acoustically, this means that the difference in distance from each projector to a point on the horizontal axis, outward from the center of the VLA, must be less than one-quarter an acoustic wavelength. For SURTASS LFA sonar, this condition is satisfied at a range in the "far-field" on the order of hundreds of meters. Only at this point is the full system capability focused in a beam. Because this point is hundreds of meters from the VLA itself, transmission losses (TL) cause the sound level there to be approximately 40 to 50 dB less than the "effective" source level. "Effective" source level is a theoretical value, hypothetically measured at 1 m from the array on its horizontal axis, calculated from the formula:

$$\text{Effective Source Level} = SL + 20 \text{ Log10}(N),$$

where SL = SL of an individual projector and N = number of projectors. Another way of illustrating this phenomenon is to visualize the way individual projectors sum as the horizontal range from the array increases. At a very short range in the "near-field" (for example, 10 m [33 ft]), the levels from only two or three projectors will be coherently combined, as the others are too far away to contribute an equivalent amount of power.

The transmitted signals from the VLA are a combination of individual, frequency-modulated (FM), and continuous wavelength (CW) signals, with a bandwidth ≤30 Hz and a total average duration of about 60 sec. The LF sonar transmissions are repeated every 6 to 10 minutes, during which time there are no other types of LF signal transmissions. As noted elsewhere, there are two somewhat different SURTASS low-frequency systems in operation, referred to as LFA (currently one system in the U.S. Navy) and CLFA (currently three systems in the U.S. Navy). The CLFA system is smaller and lighter in weight than the LFA system, but the operational characteristics of both systems are comparable, and the fundamental frequencies of both are within the 100 to 500 Hz range. For the purposes of this report we refer to the LFA and CLFA sources collectively as SURTASS-LFA sonar.

Currently there are four SURTASS-LFA sonar systems in operation. Under the current 5-year Final Rule, issued by NMFS to the U.S. Navy in August 2012, SURTASS-LFA may operate world-wide, with the only exceptions being non-operating areas (such as polar waters), Offshore Biologically Important Areas

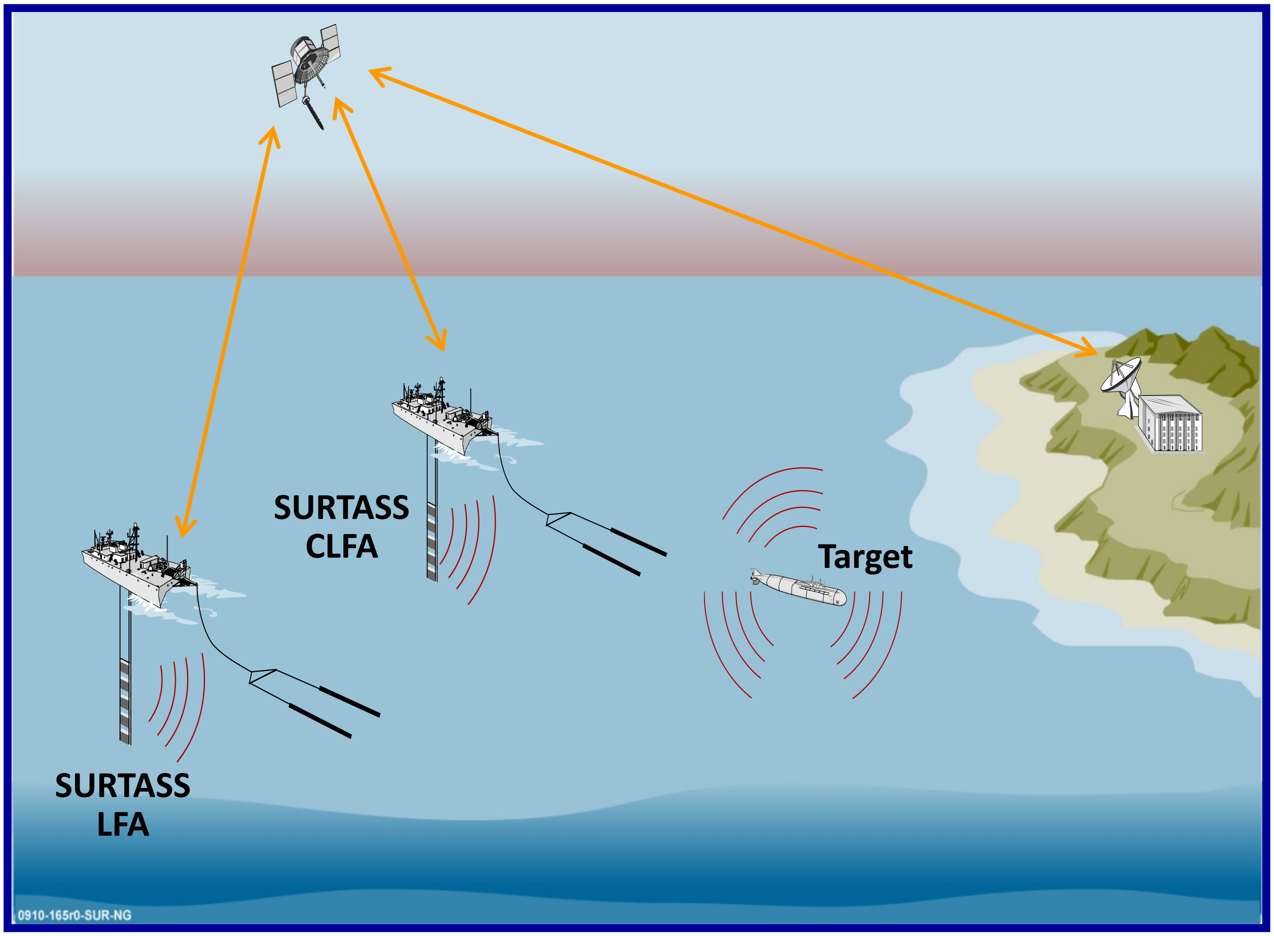

Figure 1. SURTASS LFA/CLFA Sonar Nominal Operational Scenario.

(OBIAs), and within 22 km (12 nm) from land (Figure 2). The sonar systems also operate under mitigation and monitoring requirements (including visual, passive acoustic, and active acoustic monitoring for marine mammals), and limitations on total transmission periods (no more than 432 hrs per vessel per year)[1].

A key point of discussion by the SAG concerned whether or not SURTASS-LFA sonar signals would be audible for individuals of the specific species of interest discussed in this report (beaked whales and porpoises). Of particular concern was the possibility that these high-frequency odontocete cetaceans may actually detect the higher frequency harmonics of the source better than the fundamental frequency if it is present at a sufficiently audible level. However, based on these considerations and a detailed assessment

1 For more details, please see: Federal Register, Vol. 77, No. 161, August 20, 2012, Department of Commerce, NOAA, 50 CFR Part 218: Taking and Importing Marine Mammals: Taking Marine Mammals Incidental to U.S. Navy Operations of SURTASS-LFA Sonar; Final Rule (valid from August 15, 2012 through August 15, 2017).

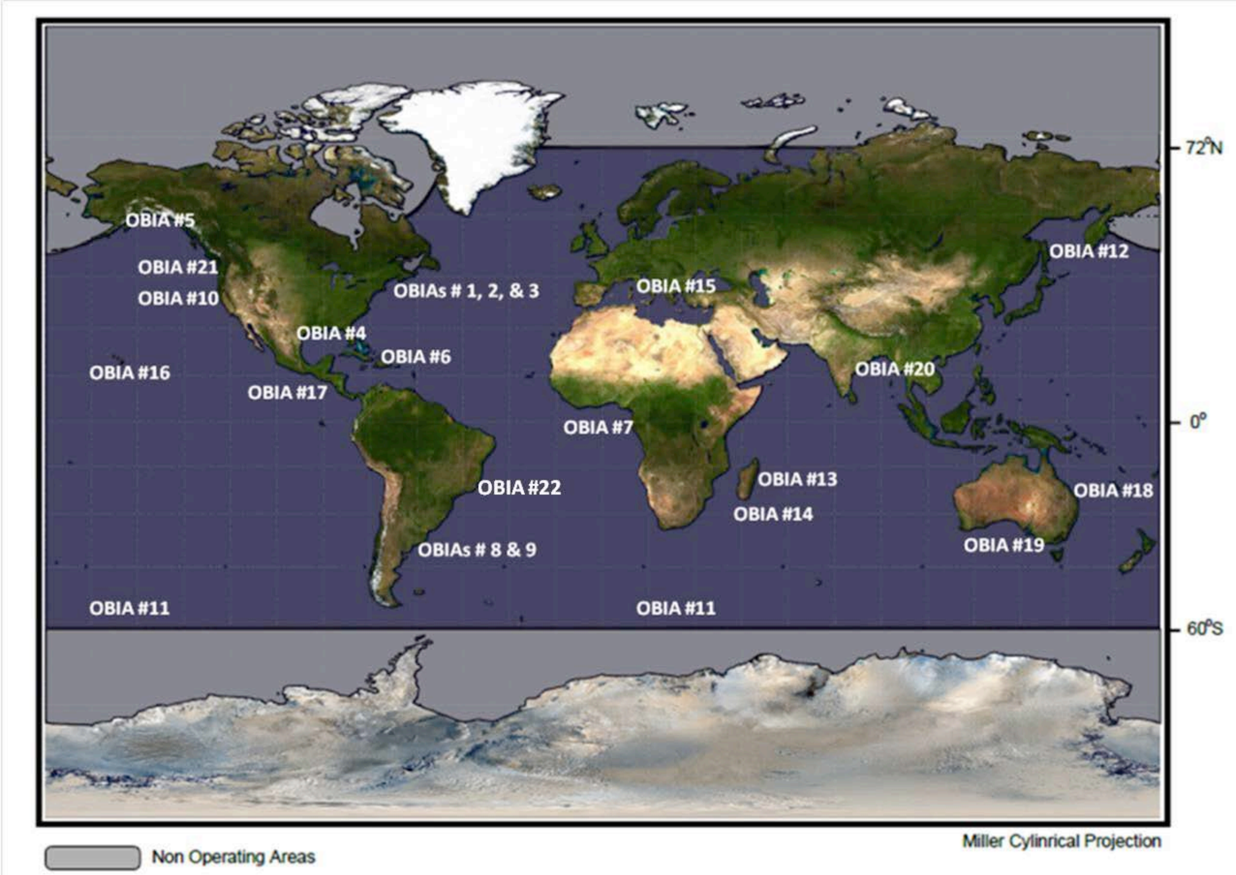

Figure 2. Worldwide operating areas for SURTASS-LFA sonar under 2012 NMFS Final Rule, with no operations in non-operating areas, within 12 nm of any shoreline, and in offshore biologically important areas (OBIAs).

by the U.S. Navy, calibrated measurements for individual LFA array projector elements as provided to the SAG, the source levels of the transmitted signals' second (twice the fundamental frequency) harmonic are ≥30 dB below the level of the fundamental frequencies, while the third and fourth harmonics are ≥45 dB below the level of the fundamental frequencies. Based on what is known about typical low-frequency hearing in marine mammals, hearing sensitivity does not improve with increasing frequency this rapidly. The decrease in the level of the source at the harmonic frequencies relates to a decrease in the audibility of the SURTASS-LFA signal as well as a decrease in potential adverse effects that could be experienced by the mammals upon hearing the sound.

3 SPECIES GROUPS OF INTEREST—OVERVIEW AND CHARACTERIZATION

3.1 PORPOISES

The family Phocoenidae consists of three genera. The genus *Phocoena* consists of four species of porpoises: the harbor porpoise (*Phocoena phocoena*), the vaquita (*P. sinus*), the spectacled porpoise (*P.*

dioptrica), and the Burmeister's porpoise (*P. spinipinnis).* The genus *Phocoenoides* includes only the Dall's porpoise (*P. dalli*), while the genus *Neophocaena* includes only the finless porpoise (*N. phocaeniodes)*. In the northwestern Pacific Ocean, the main area in which SURTASS-LFA sonar has been deployed to date, only the harbor porpoise, Dall's porpoise, and the finless porpoise are known to occur. As SURTASS-LFA sonar is presently used (primarily in the northwestern Pacific and outside of the 12-nm coastal exclusion area and OBIAs), the potential for direct spatial overlap with many of the highly-coastal phocoenids, particularly the harbor porpoise, appears to be quite limited (as discussed below). However, it is noted that future SURTASS-LFA sonar missions may be authorized in other geographic regions where this may not be the case. Additionally, certain phocoenid species, notably Dall's porpoise, have a much less coastally-restricted distribution and may be more likely to encounter SURTASS-LFA sonar signals. Presuming that porpoises do in fact encounter SURTASS-LFA sources, we consider the potential for hearing and behavioral response and propose using the disproportionately large amount of available information for the harbor porpoise to inform assessment of the other, less studied, porpoise species.

Based largely on the highly coastal distribution of the harbor porpoise, their successful maintenance in captive laboratory settings, and because of interest in their responses to other human noise-generating activities (*e.g*., pingers on fishing nets, marine construction activities), more is known about hearing, the effects of noise on hearing, and behavioral responses to different sound types in harbor porpoises than for any of the other phocoenid species. We acknowledge that there are limitations in the extent to which information from one species may be applied to other members of the same taxa. However, given that certain aspects of hearing systems (*e.g.*, general band of hearing sensitivity) are expected to be similar in closely related species and these species share some life history traits, the approach taken here was to use the larger body of scientific and field observations on harbor porpoises as a first-order approximation for considering potential effects of SURTASS-LFA sonar on other phocoenids. The accessibility of harbor porpoises in captive settings also provides a more practical option for additional, appropriate investigation than for other species that are not presently viable options for such studies.

This overall approach represents a precautionary assessment, provided that any available scientific or anecdotal information for other phocoenids does not suggest more sensitive hearing or behavioral responsiveness to sound. Little is known about hearing in Dall's and finless porpoises, or their species-typical responses to sounds. There are also no known differences in finless porpoise auditory anatomy that would suggest a deviation from the harbor porpoise.

Generalizing behavioral responsiveness across species is more challenging than for hearing, given the known contextual and other differences, including life history patterns, and social structure. The available anecdotal information in other porpoise species would suggest that they may be more tolerant of noise than the harbor porpoise. For instance, the Dall's porpoise is known to bow-ride and be more approachable in the field by researchers, suggesting they may be less averse or even potentially attracted to some human activities. While such differences should be recognized and extrapolation viewed with appropriate caution, given a) the taxonomic relationships within the phocoenids; b) available information on harbor porpoises indicating their heightened behavioral sensitivity (discussed more below); and c) the accessibility of harbor porpoises in laboratory settings, we believe that, especially with regard to hearing, it is appropriate to use the disproportionately large amount of available information for the harbor porpoise to inform assessment of the other, less studied, porpoise species. Harbor porpoise hearing and behavioral responses to different sounds are thus considered in more detail.

The harbor porpoise is widely distributed in the Northern hemisphere and a comprehensive body of published literature and anecdotal field observations support the conclusion that they are particularly sensitive to underwater noise relative to other marine mammals (Southall *et al*. 2007). The SAG's consensus opinion is consistent with this general assessment, with the realization that potential behavioral responses critically depend on the area over which they may encounter and detect a stimulus in question. Harbor porpoises have functional hearing (auditory thresholds within 70 dB of best sensitivity) over a broad (~250 Hz to 160 kHz) frequency range (Kastelein *et al*. 2010; Figure 3). They have been documented to behaviorally respond clearly, and relatively strongly, to a wide variety of underwater sounds, including pingers, various sonars, and realistic pile-driving operations (see: Southall *et al.*, 2007; Tougaard *et al*. 2009; Brandt *et al*. 2011; Kastelein and Jennings 2012; Dähne *et al*. 2013).

Porpoises are relatively small odontocetes and are therefore preyed upon by other marine animals and, as such, may rely on sound to alert them to the presence of potential predators. This may, in part, explain the documented evidence and field experiences that indicate relatively strong behavioral responses of some phocoenids (notably the harbor porpoise) to underwater sounds produced by humans. Therefore, there is the potential for harbor porpoises (or by extrapolation, other phocoenid species, based on the above assumption and the caveat that there is likely variance among species, particularly regarding behavioral responses) to be negatively influenced by LFA sonar where their distribution overlaps with SURTASS-LFA sonar mission areas (see Section 4 below). Due to their relatively small size and correspondingly large surface-to-volume ratio, harbor porpoises have to eat a relatively large amount (as percentage of body weight) of food per day (Kastelein *et al*. 1997a) and must feed relatively often (Kastelein *et al*. 1997b). Thus, if foraging harbor porpoises were to respond to LFA sonar by terminating foraging dives, this could have effects on their individual fitness.

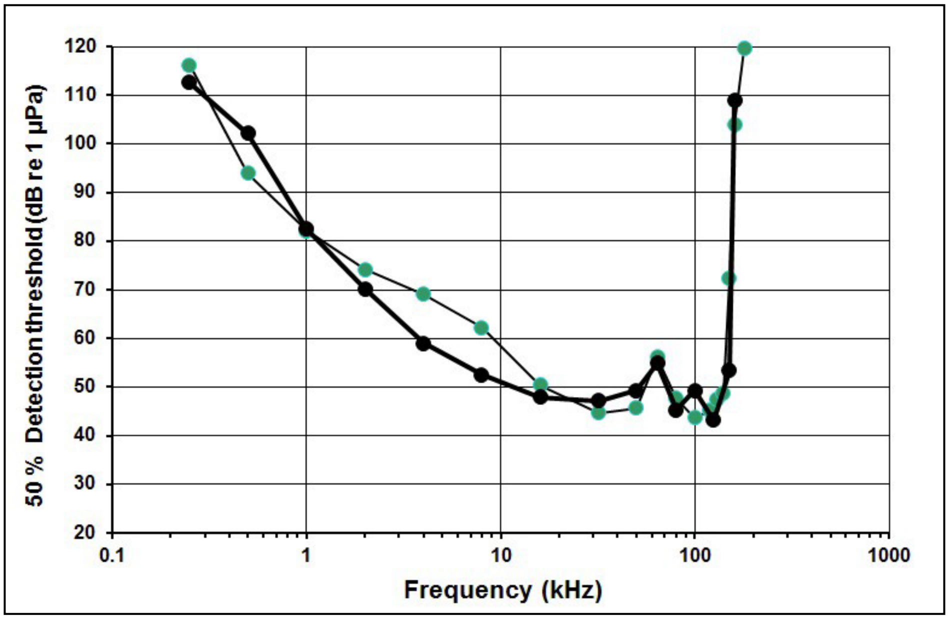

Figure 3. Audiograms of two harbor porpoises (Kastelein *et al*. 2002 and 2010).

Note that the slope of the left side of both curves decreases from 115 dB to 55 dB as the frequency increases from 250 Hz to 10,000 Hz. This dB drop is an indication of each animal's increased auditory sensitivity as the frequency of the sound stimulus increases from 250 to 10,000 Hz.

Based on the best available current information, harbor porpoises have relatively poor hearing at low frequencies (<1 kHz), although they have not been tested below 250 Hz, which includes some of the fundamental frequency energy of SURTASS-LFA sources. Based on the hearing characteristics shown in Figure 3 and the expected continuation of the low- frequency "roll off" in hearing sensitivity (*i.e.*, higher thresholds at lower frequencies), the harbor porpoise would likely only hear the fundamental frequency of SURTASS-LFA sonar, and only if they are within several kilometers of the sound source.

Harmonics may also influence behavioral responses: 1) by making sounds more audible if hearing sensitivity improves more rapidly than received levels of harmonic frequencies are reduced, relative to the fundamental frequency (Kastelein *et al*. 2012; Figure 4); and 2) by changing the perception of sounds with harmonics relative to those without. The ocean acts as a high- frequency filter (high-frequency sounds are absorbed more than low-frequency sounds). Because of this physical reality in underwater acoustics, received sounds that contain prominent harmonics above the fundamental frequency may be perceived as being produced by nearby sources, and thus, as potentially more threatening.

In the example illustrated in Figure 4 (Kastelein *et al*. 2012), the effective sensation level (number of dB above the hearing threshold for a particular frequency) for 1 to 2 kHz sweeps with harmonics (6 to 7 kHz)

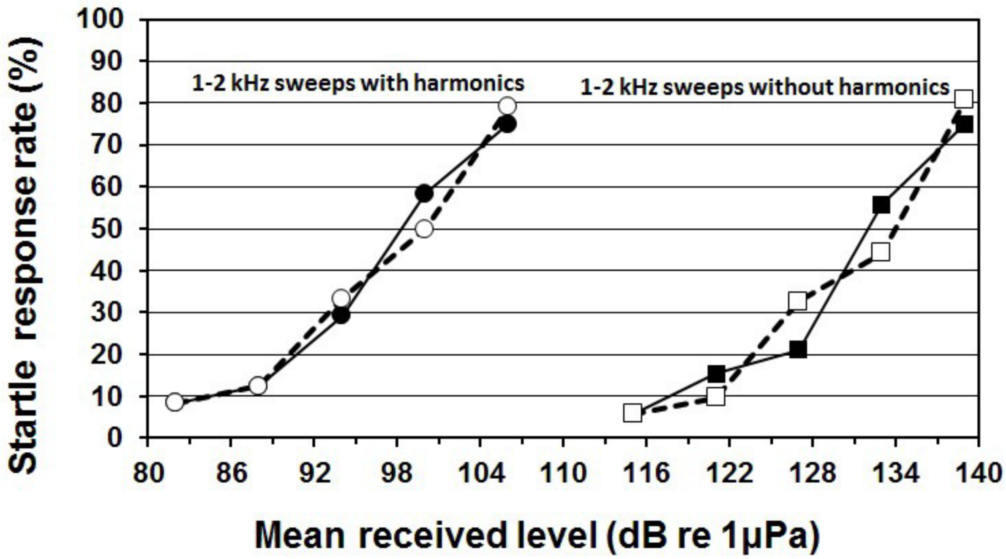

Figure 4. The mean received sound pressure level (SPL) versus the startle response rate of a harbor porpoise to two different up-sweeps and down-sweeps.

Note: Each data point is based on 24 sweep emissions. ■ = 1-2 kHz up-sweep and □ = down-sweep, both without harmonics; ● = 1-2 kHz up-sweep and ○ = down-sweep, both with harmonics around 6-7 kHz (adapted from Kastelein *et al*., 2012).

was greater than the effective sensation level for sweeps with only the fundamental frequency (1 to 2 kHz).

This result illustrates the importance of considering harmonics when assessing potential behavioral responses to an anthropogenic signal. However, because the SURTASS-LFA sources have much lower level harmonics relative to their fundamental frequencies (at least 30 dB down), it is much more likely that a harbor porpoise would detect and possibly react to SURTASS-LFA sonar's fundamental frequencies rather than the harmonics of the system.

While the SAG clearly recognizes the challenges and limitations inherent in projecting the results of captive behavioral response studies to scenarios involving free-ranging animals, recent experiences with harbor porpoises exposed to simulated and actual pile-driving noise suggest that captive studies may provide a reasonable first order approximation of responses in some free-ranging conditions. Recent data (Kastelein *et al*. in prep) suggest that under low ambient noise conditions, harbor porpoises strongly avoid locations where they are exposed to broadband sound pressure levels (SPLs) above 143 dB re 1 µPa, estimated to be at a distance of around 30 km (16.2 nm) from actual pile-driving operations. Tougaard *et al*. (2009) studied behavioral reactions of harbor porpoises to underwater noise from the pile-driving of 4 m (13 ft)-diameter steel mono-pile foundations for offshore wind turbines in the North Sea. Quantifying the echolocation activity of harbor porpoises, Tougaard *et al*. (2009) found reduced echolocation activity in harbor porpoises as far as 21 km (11.3 nm) from the pile-driving. Dähne *et al*. (2013) reported similarly strong avoidances of harbor porpoises within 20 km (10.8 nm) of a pile-driving source, based on visual surveys, while static acoustic monitoring revealed reduced echolocation at distances less than 10.8 km (5.8 nm), and an increase in detection rates at 25 km (13.5 nm) and 50 km (27 nm) from the sound source. The field results of avoidance responses for harbor porpoises were thus reasonably predicted by the laboratory assessments of response probability for this type of noise.

3.2 BEAKED WHALES

Beaked whales (family Ziphiidae) are among the most diverse and species-rich taxa of odontocete cetaceans, comprising at least 21 different species. Despite their diversity and relatively broad apparent distribution (globally from tropical to polar environments), relatively little is known about their life histories, ecology, sensory biology, or typical behavioral patterns. However, there are general patterns in their life history and ecology that all species appear to have in common. While there is some diversity among species, collectively beaked whales appear to be very deep-diving, pelagic species that feed primarily on squid and to a lesser extent on mesopelagic fishes. Little is known about the social structure and mating systems of most species, but beaked whales are typically cryptic animals that (with some exceptions) occur in relatively small social groups. Their known or expected occurrence in offshore areas with relatively deeper (>1,000 m [3,281 ft]) water is particularly important with regard to their potential exposure and responses to SURTASS-LFA sonar systems (as discussed below).

Several species of beaked whales have been disproportionately represented in mass stranding events in association with military mid-frequency active (MFA) sonar training operations (Cox *et al*. 2006; D'Amico *et al*. 2009). The overall frequency of occurrence of sonar use and marine mammal strandings makes it difficult to statistically establish a relationship by coincidence or correlation alone because no diagnostic symptoms of sonar effect have yet been discovered. However, these events and other observations of responses to anthropogenic sounds in some beaked whale species (*e.g.,* Aguilar de Soto *et al*. 2006; Carretta *et al*. 2008; Tyack *et al.* 2011) have contributed to a growing awareness of their apparently greater sensitivity (relative to most other marine mammals) to a variety of human sounds (see Southall *et al*. 2007). This has also motivated considerable recent research that has significantly advanced basic scientific understandings of behavior, life history, and effects of noise on some beaked whale species. The underlying causes of the sonar-associated stranding events remain poorly understood (Hooker *et al*. 2012), but based on observed patterns in some of the more well-documented events, much of the focus of this research has centered on behavioral responses to sound.

Tyack *et al*. (2011) used various experimental and observational methods with Blainville's beaked whales (*Mesoplodon densirostris*) in the Bahamas to demonstrate clear and sustained avoidance behavior at moderately low sound exposure levels to mid-frequency sonar signals. These experiments included tagged individuals in controlled exposure experiments (CEEs) and satellite-tagged individuals, and passive acoustic monitoring around mid-frequency active (MFA) sonar training operations. Ongoing research off southern California that focuses on the beaked whale species most commonly represented in previous mass stranding events (Cuvier's beaked whale [*Ziphius cavirostris*]) has yielded similar observations with simulated MFA CEEs, with the onset of responses occurring at even lower received levels than in the Bahamas (Southall *et al*. 2012; DeRuiter *et al*. 2013). An important observation, however, was that while strong responses to nearby, controlled exposures to simulated MFA sonar were measured by DeRuiter *et al.* (2013), the authors did not detect similar responses to distant, incidental exposure to naval sonar exercises at comparable received levels. Potential differences in response relating to these different sound exposure contexts, including the use of controlled exposures to real sonar operations, should be explored in future experiments.

While the available information remains limited to a relatively small number of species, individuals, and situations, at least some beaked whale species appear (like the harbor porpoise) to be particularly sensitive to several different types of human sounds. However, the behavioral responsiveness of beaked whales to low-frequency sounds has not been investigated. Given the above observations, it may be reasonable to consider whether this general sensitivity may extend to frequencies below several kHz.

One key question to address regarding potential behavioral responses is the extent to which such sounds are audible to the whales. Odontocete cetaceans, including beaked whales, have specialized auditory systems that rely on the production and reception of high to very high frequency (many tens of kHz) echolocation signals for locating objects. Social signals in most odontocetes may be lower in frequency but are typically at least several kHz (very little documented information exists for the social sounds of beaked whales).

Beaked whales have never been successfully maintained in captive situations for long periods of time. Consequently there are no beaked whale hearing data using trained animals responding to sounds of different frequencies to compare with the harbor porpoise audiograms shown above (Figure 3). In a few rare cases, stranded individuals were kept alive in pools for periods of hours to days. There have been several studies capitalizing on these situations to obtain the only directly available information on beaked whale hearing, including two individual Gervais' beaked whales in separate studies (Cook *et al*. 2006; Finneran *et al*. 2009) and an individual Blainville's beaked whale (Pacini *et al*. 2011). These studies used evoked potential audiometry to obtain useful information on the auditory responses of these individuals, where the responses were based on the animal's neurophysiological responses to sounds. However, these methods are functionally limited to testing hearing above about 5 kHz as a result of internal noise from animal movements, typical ambient noise in testing enclosures, and other methodological factors.

From this information, the auditory systems of these individuals at frequencies >5 kHz appear to be quite similar to those of most other odontocete cetaceans, including the well-documented bottlenose dolphin (*Tursiops truncatus*). Though the few available studies on beaked whale hearing with electrophysiological measurements do not include low frequencies, their similar overall frequency range of hearing and other characteristics suggest some functional similarities to other odontocetes. Thus, as a first-order approximation, the SAG believes it would be reasonable at this point to consider that beaked whales would have similar low-frequency hearing sensitivity and similar potential susceptibility to noise-induced hearing effects at low frequencies as the relatively well-studied bottlenose dolphin.

4 BROAD ASSESSMENT OF SPATIAL OVERLAP OF SURTASS-LFA MISSION AREAS WITH BEAKED WHALES AND PORPOISES

While the hearing thresholds of marine animals provide essential information on the likelihood that an animal will hear the sound, hearing is only part of the determination that an animal could be affected by SURTASS-LFA sonar activity. Another consideration is whether the animal will be exposed to the SURTASS-LFA sound in a SURTASS-LFA sonar mission area. In other words, the animals must be in the vicinity of the sound source and the source must be operating for the animal to be exposed to the sound, with the probability of response depending on whether or not the animal can detect those sounds and the level of the response, depending on a combination of issues, including relative received level and contextual factors. Thus, as a first step in an assessment, it is essential to have information on the distribution of the animals relative to the proposed operational environment of the SURTASS-LFA sonar (Figure 2). From this perspective, porpoises and beaked whales have fundamentally different preferred habitats and are thus likely to have very different probabilities of being exposed to SURTASS-LFA sonar signals.

While the distribution and abundance of beaked whales is poorly known, we do know generally that they are deep-diving pelagic whales that inhabit the offshore waters of all oceans (Mead 2009). There are a number of species that are known to occur within the current operational areas of SURTASS-LFA sonar in the northwestern Pacific, including Cuvier's beaked whale, Baird's beaked whale, northern bottlenose whale (*Hyperodon ampullatus*), and several species of *Mesoplodon* spp. These whales are likely to be more present in the offshore (>1,000 m [3,281 ft] deep) regions where many SURTASS-LFA sonar mission areas are found, and would be considered a species group that may be exposed to sound emissions from SURTASS-LFA sonar operations. Unfortunately, these species are also among the least known of all cetacean species, and their distributions, densities, and even species composition are not well known in SURTASS-LFA sonar mission areas.

As mentioned earlier, only the harbor porpoise, Dall's porpoise, and the finless porpoise occur within the region where SURTASS-LFA sonar operates currently. Unless SURTASS-LFA sonar operations extend beyond the nominal mission areas in the northwestern Pacific Ocean and the north-central Pacific Ocean, as authorized by NMFS, the vaquita, spectacled porpoise, and Burmeister's porpoise would not be exposed to SURTASS-LFA signals and thus, would not be affected. Given that the harbor and finless porpoises are restricted to the coastal zone, there are very few regions within the mission areas of SURTASS-LFA sonar in which these species would likely be encountered. Thus, there is a very low probability of an adverse effect on these species from exposure to SURTASS-LFA sonar; a concise description of their distributional ranges follows below. For the more pelagic Dall's porpoise, the probability of overlap may be greater.

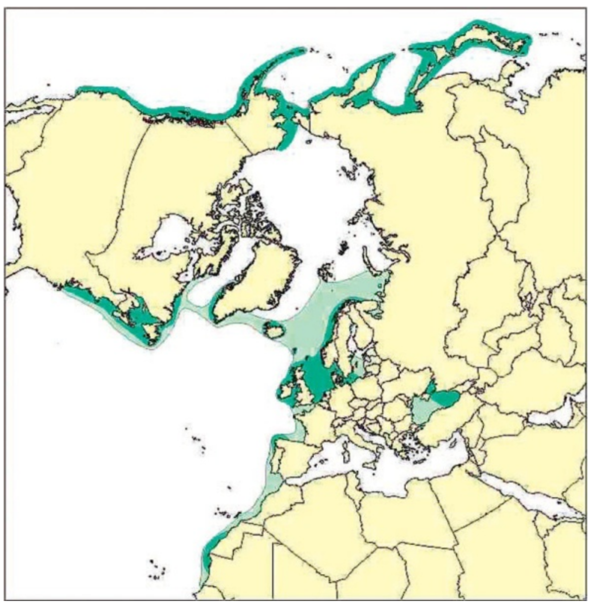

Figure 5. Distribution of harbor porpoise (from Bjørge and Tolley 2009).

The harbor porpoise is a cosmopolitan species occurring throughout the coastal waters (primarily remaining on the continental shelf) of the North Pacific, North Atlantic and Black sea (Figure 5). In the North Pacific its range extends from California through the Bering Sea and Aleutian Islands down the coast of Russia to southern Japan (Bjørge and Tolley 2009).

The finless porpoise is also a coastal species found in continental shelf waters. As a warm-water species, the finless porpoise's range overlaps with the harbor porpoise's southern boundary (Figure 6).

The Dall's porpoise is a cold-water species unique to the North Pacific Ocean, with a distribution that ranges from California and southern Japan to the Aleutian Islands. This porpoise is an oceanic species that is often found offshore in deep oceanic waters, but they are also found along the deep continental slope waters off California (Jefferson 2009).

Given the distribution of Dall's porpoise, it must be considered as a species that has a greater potential to be in the vicinity of sound emissions from SURTASS-LFA sonar operations.

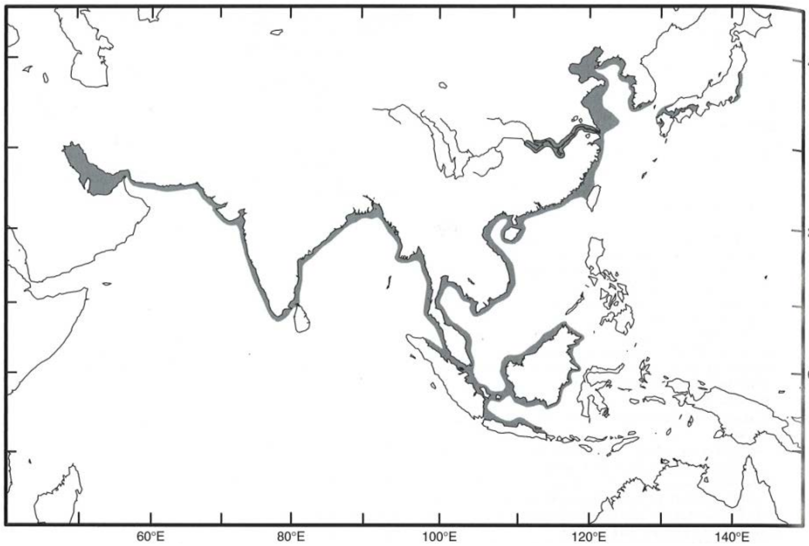

Figure 6. Distribution of finless porpoise (from Amano 2009).

5 SUMMARY OF 1997-98 LOW FREQUENCY SOUND SCIENTIFIC RESEARCH PROGRAM

In 1997 and 1998, a three-phase experiment was undertaken to quantify the responses of selected baleen whale species to powerful, low-frequency acoustic broadcasts, including those of the U. S. Navy's SURTASS-LFA sonar system. The three phases of the Low Frequency Sound Scientific Research Program (LFS SRP) tested whale responses under three different behavioral and ecological contexts: foraging, migrating, and mating.

The first phase was conducted during September and October 1997 in the waters of the Southern California Bight to the west of San Nicholas Island in an area where blue whales (*Balaenoptera musculus*) and fin whales (*Balaenoptera physalus*) congregate in the late summer and fall to feed. For this experiment, the research team used the actual SURTASS-LFA system operated by U.S. Navy personnel on the R/V *Cory Chouest*. The interdisciplinary research design included:

1. An aerial survey team that visually surveyed the research area to map the distributions of blue and fin whales.
2. An independent vessel survey team (unaware of periods of sound transmission) who conducted focal follows and deployed a towed hydrophone array to evaluate the behavioral responses of individual animals before, during, and after playback of SURTASS-LFA sonar.

3. A tagging team that tagged and photo- identified blue and fin whales to determine dive-depth-time characteristics for animals throughout days with and without SURTASS-LFA sonar transmissions.

4. Visual observers aboard the R/V *Cory Chouest who* conducted visual observations before, during, and after SURTASS-LFA sonar transmissions.

5. Acoustic observers aboard the R/V *Cory Chouest* who, using the ship's towed hydrophone array system, recorded and monitored the acoustic activities and locations of blue and fin whales before, during, and after SURTASS-LFA sonar transmissions.

During SURTASS-LFA sonar transmissions, 12 to 30 percent of the estimated received levels on blue and fin whales in the study area exceeded 140 dB re 1 μPa. Whales continued foraging in the region, and whale encounter rates and diving behaviors appeared to be more strongly linked to changes in prey abundance associated with oceanographic parameters than to SURTASS-LFA sonar transmissions. At the spatial and temporal scales examined, no obvious responses of whales were observed (Croll *et al*. 2001).

The second phase of the LFS SRP focused on gray whales (*Eschrichtius robustus*) migrating southward off Point Buchon on the central California coast (Clark and Tyack 1999). The protocol followed the protocol used in earlier studies off central California (Malme *et al*. 1983). In this context, the R/V *Cory Chouest* did not deploy the SURTASS-LFA sonar system, but instead, LFA sonar playback was achieved using a single LFA sonar transducer deployed from a boat moored 1.9 or 3.7 km (1 or 2 nm) offshore. Results revealed that migrating gray whales avoided the source vessel when it was in the 1.9 km (1 nm) offshore location, which was close to the central axis of their migration corridor, and the LFA sonar was transmitting, and the amount of avoidance was generally proportional to the estimated received levels at the whales. However, this effect disappeared when the source was located in the 3.7 km (2 nm) offshore position, which was on the edge of their migration corridor, regardless of LFA sonar source level and estimated received levels at the whales. This result raised questions about the interpretation of the responses at the 1.9 km (1 nm) offshore position and supported the conclusion that context can be a significant factor in responses to LFA sonar signals (Ellison *et al*. 2012).

The third phase of the LFS SRP focused on humpback whale (*Megaptera novaeangliae*) singers off the island of Hawai'i, using the R/V *Cory Chouest* and the SURTASS-LFA sonar system. Analysis of a small sample of focal-followed singers indicated that some males lengthened their songs (Miller *et al*. 2000), but a richer statistical analysis of song length indicated that SURTASS-LFA sonar activity explained only a very small portion of overall variation in song length (Fristrup *et al*. 2003). Overall, there was no observed change in distribution of whales based on visual observations, and although singers sometimes responded to the sonar, they resumed normal activity within tens of minutes.

6 SAG ASSESSMENT OF POTENTIAL RESEARCH QUESTIONS AND METHODS FOR PORPOISES AND BEAKED WHALES

The SAG reviewed the information presented on the unclassified operating characteristics of the SURTASS-LFA sonar system; the currently available data on life history, hearing, and behavioral reactions of beaked whales and porpoises to a range of sound types; potential spatial overlap between SURTASS-LFA sonar operations and these species; and previous research on SURTASS-LFA sonar effects on baleen whales. As directed in the TOR, the SAG then identified potential research questions and possible methods to address the potential for harbor porpoises and beaked whales to detect and behaviorally respond to SURTASS-LFA sonar. The SAG also assessed the feasibility, cost/benefit, and value to the U.S. Navy of these potential research studies.

The SAG undertook a systematic approach to initially identify broadly applicable questions that could be addressed through laboratory or field studies that assessed the potential behavioral responsiveness of beaked whale and porpoise species to SURTASS-LFA sonar (though the questions would apply broadly to any species). These broad questions and their applicability to laboratory or field studies were comprised of the following:

- At what sound levels would SURTASS-LFA sounds be audible? (*laboratory*)
- Under what exposure conditions would SURTASS-LFA signals be expected to induce observable behavioral responses in individuals or groups of the focal species? (*field and laboratory*)
- Is there general avoidance of areas in which the SURTASS-LFA source is operating? (*field*)
- What sound levels would be expected to induce temporary threshold shift (TTS), and how would this information be used to determine behavioral sound exposure criteria? (*laboratory*)

With these basic research questions identified, the SAG characterized the potential research and monitoring approaches that could be used to address them within the two taxonomic groups. Specific studies within these approaches were identified as well as the presence, or lack of, existing data. Each of these potential studies was examined in terms of its feasibility, whether current methods exist or would need to be developed to conduct the study, and a broad scoring of their likely cost broken into three categories ($10K to 100K, $100K to 1,000K, and above $1,000K). Finally, to develop a strategically prioritized research and monitoring plan, the panel conducted an overall assessment of the value of each of these potential studies in the context of research needs, feasibility, cost, and likely return on investment. The results of the SAG's assessment of potential harbor porpoise and beaked whale research follow (Tables 1 through 4).

7 CONCLUSIONS AND RECOMMENDATIONS

The SAG provides the following conclusions and recommendations regarding studies and monitoring of SURTASS-LFA sonar in relation to beaked whales and harbor porpoises.

A. Given the paucity of information on beaked whale and porpoise species hearing and potential behavioral responsiveness to underwater anthropogenic sound, some extrapolation of information from a few better-known species to those in related taxa was necessary. However, this should be approached with some caution, particularly regarding behavioral responses and their potential significance. In terms of hearing and effects of a wide variety of different kinds of sound exposure, harbor porpoises are by far the most extensively studied of the porpoises. At present, they are the only species held in captive facilities in which the studies outlined here could readily be conducted, although the extrapolation of these data to other phocoenids is most appropriate for assessment of hearing characteristics. For beaked whales, direct measures of hearing at relevant frequencies (100 to 500 Hz) are not available, but the very limited electrophysiological data on a few stranded animals at higher frequencies suggest that beaked whales are functionally similar to other medium-sized odontocetes, such as bottlenose dolphins. Therefore, the use of low-frequency behavioral hearing data from the well-studied bottlenose dolphin seems an appropriate surrogate for predicting beaked whale hearing capabilities (not behavioral responses). Based on the limited behavioral response data for free-ranging beaked whales of three species (i.e., Blainville's, Cuvier's, and Gervais' beaked whales, which are discussed in more detail above), there appears to be some general similarities in their elevated responsiveness to various human sounds relative to other marine mammals.

B. Given present knowledge of hearing in these taxa and how SURTASS-LFA sonar is operated, the potential effects on beaked whales and porpoises are expected to be limited. However, the SAG concurs with previous assessments (based on both published laboratory and field studies as well as field observations from experienced researchers, including members of the SAG) that in general, these taxa do appear to react to a variety of sounds more readily and strongly than other marine mammal species studied. In our view, given this assessment and the fact that species in these two taxa likely can detect the fundamental frequencies of SURTASS-LFA sources over ranges of no more than several kilometers, it is not possible, at present, to entirely exclude some concerns about the potential influences of SURTASS-LFA sonar on these taxa. From what is

Table 1. Assessment of Potential Key Questions and Research Methods—Harbor Porpoises: Laboratory Studies.

BROAD RESEARCH QUESTIONS	GENERAL RESEARCH AND MONITORING METHODS	SPECIFIC STUDIES AND MONITORING	EXISTING DATA AVAILABLE?	FEASIBILITY, EXISTING METHODS, COST ASSESSMENT[2]	OVERALL ASSESSMENT[3]
At what levels would SURTASS-LFA sounds be audible?	*Behavioral Audiometry*	Measure hearing at relevant frequencies	YES down to 250 Hz (Kastelein *et al*., 2010)	***Highly feasible*** with existing methods **$**	Additional measurements at lower (to 100 Hz) frequencies needed; multiple subjects desirable as well as auditory filter properties
	ABR/AEP Techniques	Measure hearing at relevant frequencies	YES but not at relevant frequencies [Beedholm and Miller 2005]	***Not possible*** below a few kHz	Not feasible for relevant frequencies (due to internal noise from animal movements, typical ambient noise in testing enclosures, and other factors)
At what levels would SURTASS-LFA sounds be expected to induce observable behavioral responses?	*Observational methods*	Brief changes in speed, direction, respiratory patterns	NO	***Highly feasible*** with existing methods (with realistic background noise levels) **$**	Useful to identify individual short-term responses in known exposure contexts; relative sensitivity to other odontocetes would be informative
		Sustained response (*e.g.*, avoidance, physiological)	NO	***Highly feasible*** with existing methods **$**	Useful to identify responses with potential fitness implications; relative sensitivity to other odontocetes would be informative
What exposures would be expected to induce TTS?	*Clinical exposure methods*	Measure TTS onset and growth at different frequencies, exposure SPL, and duration	NO but recent (Kastelein unpub. data) showed TTS for 500 Hz octave-band noise (OBN)	***Highly feasible*** with existing methods **$$**	Each parameter identified would be a different experiment; first step: onset TTS in main signal band

2 NOTE: for this and all subsequent tables: **$ = $10K to 100K $$ = $100K to 1,000K $$$ = above $1,000K**

3 Shading indicates potential topics with greater near-term potential return on investment (darker shading = higher priority; no shading = not presently recommended based on need, feasibility, cost assessment); see discussion for further consideration of suggested step-wise strategic approach.

Table 2. Assessment of Potential Key Questions and Research Methods—Harbor Porpoises: Experimental Field Studies.

BROAD RESEARCH QUESTIONS	GENERAL RESEARCH AND MONITORING METHODS	SPECIFIC STUDIES & MONITORING	EXISTING DATA AVAILABLE?	FEASIBILITY, EXISTING METHODS, COST ASSESSMENT	OVERALL ASSESSMENT
Is there general avoidance of areas of SURTASS-LFA source operation?	*Observational Monitoring*	Use passive acoustic monitoring (PAM) assets in SURTASS-LFA sonar operational areas	YES for monitoring porpoises with PAM generally but not re: LFA	Possible but ***very difficult and costly*** **$$$**	Not recommended because of level of effort, cost, sensor distribution
		Use PAM assets on instrumented U.S. Navy ranges (AUTEC in Bahamas, SCORE in southern CA, PMRF in Hawaii)	NO-species do not exist on ranges	***Not applicable***	Not applicable
		Use long-term monitoring satellite tags to monitor movement relative to SURTASS-LFA field operations	NO	***Not presently feasible*** based on field experience with these species	Not recommended
Are there identifiable individual behavioral responses to SURTASS-LFA sounds?	*Experimental (CEE) methods*	Tagging/focal follow studies to measure individual responses with high-resolution acoustic and movement sensors in controlled conditions	NO	***Not presently feasible*** based on field experience with these species	Not recommended

Table 3. Assessment of Potential Key Questions and Research Methods—Beaked whales: Laboratory Studies[4].

BROAD RESEARCH QUESTIONS	GENERAL RESEARCH AND MONITORING METHODS	SPECIFIC STUDIES & MONITORING	EXISTING DATA AVAILABLE?	FEASIBILITY, EXISTING METHODS, COST ASSESSMENT	OVERALL ASSESSMENT
At what levels would SURTASS-LFA sounds be audible?	*Behavioral Audiometry*	Measure hearing at relevant frequencies	NO	***Not presently feasible*** with existing methods	All previous efforts to maintain these species in captivity for sufficient periods have been unsuccessful Audibility should be assessed using related species and anatomical modeling
	ABR/AEP Techniques	Measure hearing at relevant frequencies	YES but not at relevant frequencies [Cook *et al*., 2009; Finneran *et al*., 2009; Pacini *et al*., 2011]	***Not possible*** below a few kHz	Not presently feasible for relevant frequencies; research opportunities very limited
At what levels would SURTASS-LFA sounds be expected to induce observable behavioral responses?	*Observational methods*	Brief changes in speed & direction	NO	***Not presently feasible*** since subjects currently unavailable in laboratory settings	Not presently feasible
		Sustained response (*e.g.*, avoidance, physiological)	NO	***Not presently feasible*** since subjects currently unavailable in laboratory settings	Not presently feasible
What exposures would be expected to induce TTS?	*Clinical exposure methods*	Measure TTS onset and growth at different frequencies, level, and duration	NO	***Not presently feasible*** since subjects currently unavailable in laboratory settings	Not presently feasible

4 Beaked whales have not been successfully maintained in captivity to date, but a number of important research questions regarding this and other issues could be addressed if an animal was successfully held in a laboratory setting for a sufficient period of time. While this may be unlikely, contingency planning should be considered if the opportunity arose.

Table 4. Assessment of Potential Key Questions and Research Methods—Beaked whales: Experimental Field Studies

BROAD RESEARCH QUESTIONS	GENERAL RESEARCH AND MONITORING METHODS	SPECIFIC STUDIES & MONITORING	EXISTING DATA AVAILABLE?	FEASIBILITY, EXISTING METHODS, COST ASSESSMENT	OVERALL ASSESSMENT
Is there general avoidance of areas of SURTASS-LFA source operation?	*Observational Monitoring (PAM)*	Deploy large array of PAM assets in operational areas for SURTASS-LFA sonar	YES for monitoring beaked whales with PAM generally but not re: LFA	***Possible but very difficult and costly*** **$$$**	Expanding detection bandwidth of existing PAM in operational systems could allow detection of odontocetes. Dedicated PAM deployments not recommended given level of effort, cost, remote location
	Observational Monitoring (long-term monitoring of individual movement-satellite tags)	Use long-term monitoring satellite tags to monitor movement relative to SURTASS-LFA field operations	YES for monitoring movement relative to MFA operations on U.S. Navy ranges	***Possible but very difficult and costly*** **$$$**	Challenging given large, remote operation areas. Possible follow on to range-based efforts pending results
	Observational Monitoring (CEE context)	Use PAM assets on instrumented U.S. Navy ranges	YES for MFA in training operations, not LFA [McCarthy et al., 2011; Tyack *et al.*, 2011; Ward *et al.*, 2011]	***Feasible*** with adaptation of existing methods **$$**	Most feasible starting point: single LFA element in experimental context with range monitoring (SCORE or PMRF most feasible)
Are there identifiable individual behavioral responses to SURTASS-LFA sounds?	*Experimental (CEE) methods*	Tagging/focal follow studies to measure individual responses	YES for MFA, not LFA [Tyack *et al.*, 2011; Southall *et al.*, 2012]	***Feasible*** with existing methods **$$ to $$$**	If undertaken, likely should occur on U.S. Navy ranges and be integrated with existing methods for measuring individual behavior (satellite tagging, suction cup tags)

known and expected about the hearing abilities of these species, many of the potential effects considered would be mediated by hearing and likely be behavioral in nature.

C. There are fundamental differences in the life histories and distributions of beaked whales and porpoises that affect whether and how these animals would encounter SURTASS-LFA sonar. Given typical scenarios for SURTASS-LFA sonar, these differences support the conclusion that the potential for beaked whales to encounter SURTASS-LFA sonar would be much greater than for porpoises. This may affect a strategic implementation of the recommendations made in Tables 1-4 above and also has bearing on the general research methods that might be implemented in studying potential responses (Table 5).

Table 5. General Research Methodologies for Porpoises and Beaked Whales and Potential for Relative Exposure to SURTASS-LFA Sonar.

SPECIES GROUP	GENERAL DISTRIBUTION	RELATIVE EXPOSURE TO SURTASS-LFA OPERATIONS	GENERAL RESEARCH METHODOLOGIES
Porpoises	Many Species, More Coastal	***Limited*** (with possible exception of Dall’s porpoise)	**Laboratory clinical approaches** (particularly regarding hearing and TTS with some limited behavioral studies) most appropriate-similar to work already done for sonars (including LF and HF); Field methods very limited
Beaked Whales	Pelagic	***More Possible***	**Field behavioral methods most appropriate** with CEE methods using various monitoring; laboratory methods not possible (potential surrogate species for clinical trials with established methods: bottlenose dolphin)

D. There are widely different degrees of knowledge about hearing and behavioral response across species within these two taxa (*e.g.*, hearing is relatively well-measured in harbor porpoises, while hearing in all other porpoises is extrapolated from this species).

E. Any dedicated research strategy that is undertaken regarding the potential impacts of SURTASS LFA sonar on any odontocete cetaceans should follow a step-wise, strategic approach, proceeding in parallel with any subsequent effort, depending upon the results of each preceding step. This would use existing methodologies where possible, and build on existing and new knowledge that should be critically assessed to determine if any further research is required or justified.

7.1 PROPOSED STEPS FOR PORPOISE LABORATORY RESEARCH

1. Determine audibility of SURTASS-LFA sounds (with and without harmonics).
2. Based on results and conclusions from Step 1, potentially proceed to dedicated and prioritized behavioral response studies.
3. Based on results and conclusions from Steps 1 and 2, potentially proceed to dedicated and prioritized TTS studies

7.2 PROPOSED STEPS FOR BEAKED WHALE FIELD RESEARCH

1. Monitor potential beaked whale responses to scaled CEEs with SURTASS-LFA sounds.
2. Based on results and conclusions from Step 1, potentially proceed to include an integrated approach in existing U.S. Navy range areas using PAM, satellite tags, and high-resolution, suction cup acoustic/movement tags.

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APPENDIX I. SAG TERMS OF REFERENCE (TOR)

The U.S. Navy supports and conducts a variety of research and monitoring programs to better understand potential effects of sound on the marine environment during testing and training activities. While many of the present efforts relate to mid- frequency sonar, considerable effort and interest has included low-frequency sonar, specifically Surveillance Towed Array Sensor System Low Frequency Active (SURTASS-LFA) sonar. Most of this effort has focused on low- frequency specialist species, including whales and fish. However, certain odontocete species (notably beaked whales and harbor porpoise) appear to be particularly sensitive to a range of sound exposures, and their potential sensitivity to low- frequency sound sonar systems has arisen as a key consideration and research need.

During the U.S. Navy's application process for the new five- year rule for the operation of SURTASS-LFA sonar (2012-2017), discussions with the National Marine Fisheries Service (NMFS) identified the need for data to better assess potential impacts of low-frequency sound on harbor porpoises and beaked whales. In its Final Rule on the authorization for SURTASS-LFA sonar, NMFS calls for the formation of a Scientific Advisory Group (SAG) to consider various scientific and monitoring tools that could be applied in support of this research and to make specific recommendations about the feasibility, efficacy, and likely results of subsequent research and monitoring. The scope of this effort must be specific to behavioral effects from SURTASS-LFA sonar, rather than all U.S. Navy-related low- frequency sound sources**.** The SAG is intended to consist of subject matter experts in marine acoustics, bioacoustics, behavioral response studies, and the biology/behavior of beaked whales and harbor porpoises.

The SAG recommendations will be derived from one or several coordinating conference calls leading up to a two- day meeting, from which will be generated draft and final reports detailing the SAG findings. The Final Report will be viewed as an independent scientific assessment of a reasonable research and monitoring approach, and will be unclassified and transparent. The U.S. Navy will then assess the report and develop a plan of action for new monitoring and/or research efforts, based on feasibility.