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Dive Distribution and Group Size Parameters for Marine Species Occurring in the U.S. Navy's Pacific Surveillance Towed Array Sensor System Low Frequency Active Sonar Training and Testing Study Area

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14. ABSTRACT

An important element of the Navy's comprehensive environmental planning is the acoustic effects analysis executed with the Navy Acoustic Effects Model (NAEMO) software. NAEMO was developed to estimate the possible impacts of anthropogenic sound on marine animals, combining established acoustic propagation modeling with data regarding the distribution and abundance of marine mammals. This report recommends species-typical static depth distributions and group size information for all marine mammals that occur in the Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) Sonar Training and Testing Study Area that will be modeled using NAEMO.

15. SUBJECT TERMS

acoustic modeling, marine mammals, dive profile, group size, Surveillance Towed Array Sensory System (SURTASS), low frequency active (LFA), sonar, Navy Acoustic Effects Model (NAEMO)

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LIST OF ABBREVIATIONS AND ACRONYMS

DTAG	digital acoustic recording tag
LFA	low-frequency active
m	meter(s)
max	maximum
min	minute(s)
no.	number
NAEMO	Navy Acoustic Effects Model
NUWC	Naval Undersea Warfare Center
SD	standard deviation
sec	second(s)
SURTASS	Surveillance Towed Array Sensor System
U.S.	United States

1. INTRODUCTION

The United States (U.S.) Navy is required to assess potential impacts of Navy-generated sound in the water on protected marine species in compliance with applicable laws and regulations, including the National Environmental Policy Act, Executive Order 12114, the Marine Mammal Protection Act, and the Endangered Species Act. This report describes the methods and analytical approach to quantifying the depth distributions in the water column and group sizes of marine mammals to be used within the Navy Acoustic Effects Model (NAEMO). Although sea turtles can also be modeled using NAEMO, marine mammals were the only group modeled as proper densities were only available for this group. NAEMO is further discussed below.

1.1 THE NAVY ACOUSTIC EFFECTS MODEL

NAEMO is the standard model used by the Navy to estimate potential impacts to marine species from impulsive and non-impulsive sound sources used during Navy training and testing activities. NAEMO combines marine species distribution information with environmental parameters, propagation characteristics, sound source parameters, and typical training or testing scenarios in order to assess the level of behavioral disturbance, hearing impacts (including both temporary threshold shifts and auditory injury), and other injuries predicted for individual marine mammals likely to be in the vicinity of Navy training and testing activities.

1.2 DATA INPUTS

NAEMO first uses location-specific density and group size information (more detailed information regarding species density is available in the density technical report by the U.S. Department of the Navy (DoN 2024) to patchily distribute a given marine species into a simulation area. The depth distribution data are then used to place animals in the water column at the depths at which they are typically found. An animal is reassigned a new depth every 4 minutes (min) throughout the simulation based on the depth distribution for that species. Where available, seasonal or geographically-specific depth and group size information is used.

Density data are not available for all taxa of concern for Navy activities (Section 2). In addition to available marine mammal data, specific information about environmental conditions and projected Navy activities within a Study Area is needed to run NAEMO and quantify potential impacts to marine mammals. These environmental data include information about bathymetry, seafloor composition (e.g., rock, sand), and factors that vary throughout the year such as wind speed and sound velocity profiles. The details of Navy training and testing activities are also collected, including location, frequency, and source characteristics. For more detailed information about the NAEMO model, consult DoN (2025).

2. MARINE MAMMAL DEPTH DISTRIBUTIONS

The best available science from literature reviews was used to obtain species-specific depth distribution information for the Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) Sonar Training and Testing Study Area (Figure 2-1). Journal articles, books, technical reports, cruise reports, funding agency reports, theses, dissertations, and raw data from individual researchers were assessed for this report. Usable depth distribution data were data that presented percentage of time at depth for a species. In some cases, the closest data to this type of data were represented by the percentage of dives to a certain depth, which was sometimes used as a proxy for percentage of time in each depth bin. Some studies did not include bins but displayed continuous dive profiles over the entire duration of a tag. On these profiles, the DataTheif MATLAB program was used to generate dive profiles with depth bins.

As described in Section 1.1, depth distribution data are combined with species density data during the NAEMO modeling process. Densities were obtained from the Navy Marine Species Density Database. In some instances, density data were provided for guilds of species, rather than for individual species (i.e., beaked whales). These multi-species guilds were created because observers could not differentiate closely-related species at sea or because the sample sizes of the species observed individually were too small to incorporate into density modeling. For these cases, a single representative species was chosen or a composite depth distribution was created to correspond to the multi-species groupings contained in the density data. Each density layer had to be matched with a dive profile, which is why each guild is presented in this document.

The information required for representing a species in NAEMO specifically focuses on the percentage of time each animal spends in the water column, defined here as a range of depths extending from the surface to the maximum dive depth of each species. Within the research, percentage values may be slightly above or below 100 percent, due to decimal rounding, especially when animals spend smaller percentages of time close to their maximum dive depth. However, NAEMO requires that the percentages add to 100 percent; therefore, where applicable, if the sum was over 100, the "extra" percentage was removed from the deepest bins and, if the sum was less than 100, the difference was added to the surface bin. In all cases, this difference was less than 1 percent. Rather than reduce the deepest bin to zero during this adjustment process, the deep bins were sometimes halved in order to show a fraction of a percentage when it has been recorded that a species is capable of reaching that depth bin. For pinniped species, time spent hauled out of the water is not represented (this is accounted for in the density data). Depth distributions contain only the percentage of time spent in the water, either at the surface or in given depth bins. NAEMO requires that depth bins begin at zero and that the bin following the previous bin start and end with the same depth (i.e., the first bin would be 0–5 m and the following depth bin would be 5–10 m). If the research contained a small gap, such as where a depth bin ended at 5 m and the next started at 6 m, the depths were adjusted so that the second bin started at 5 m instead.

It should be noted that the dive profile research had to be completed by the fall of 2022 for the majority of marine mammals, before modeling began for the SURTASS LFA Sonar Training and Testing Study Area. As a result, although this document is not being published until 2025, research for this technical report largely stopped in 2022. Some dive profiles were researched after 2022 (e.g., Indo-Pacific finless porpoise) and include data from 2022 onwards.

2.1 SURROGATE SPECIES AND STUDY AREA

Depth distribution data within this report are based upon species-specific tagging data obtained during the literature review. If tagging data were not available for a particular species or guild, data for the most similar species were used in the form of a surrogate. A species will generally only be considered a surrogate for modeling if the species is closely related (within the same genus or family), feeds on similar prey, or has a distribution in similar water types (e.g., continental shelf waters). The exception to the general surrogate selection is the two species of *Kogia* spp. (dwarf and pygmy sperm whales), for which there are no other species in their family to choose as surrogates. Therefore, a species from another family within their suborder (Odontoceti) was chosen as a surrogate. Surrogate species (if required) are provided in Table 2-1 for the SURTASS LFA Sonar Training and Testing Study Area.

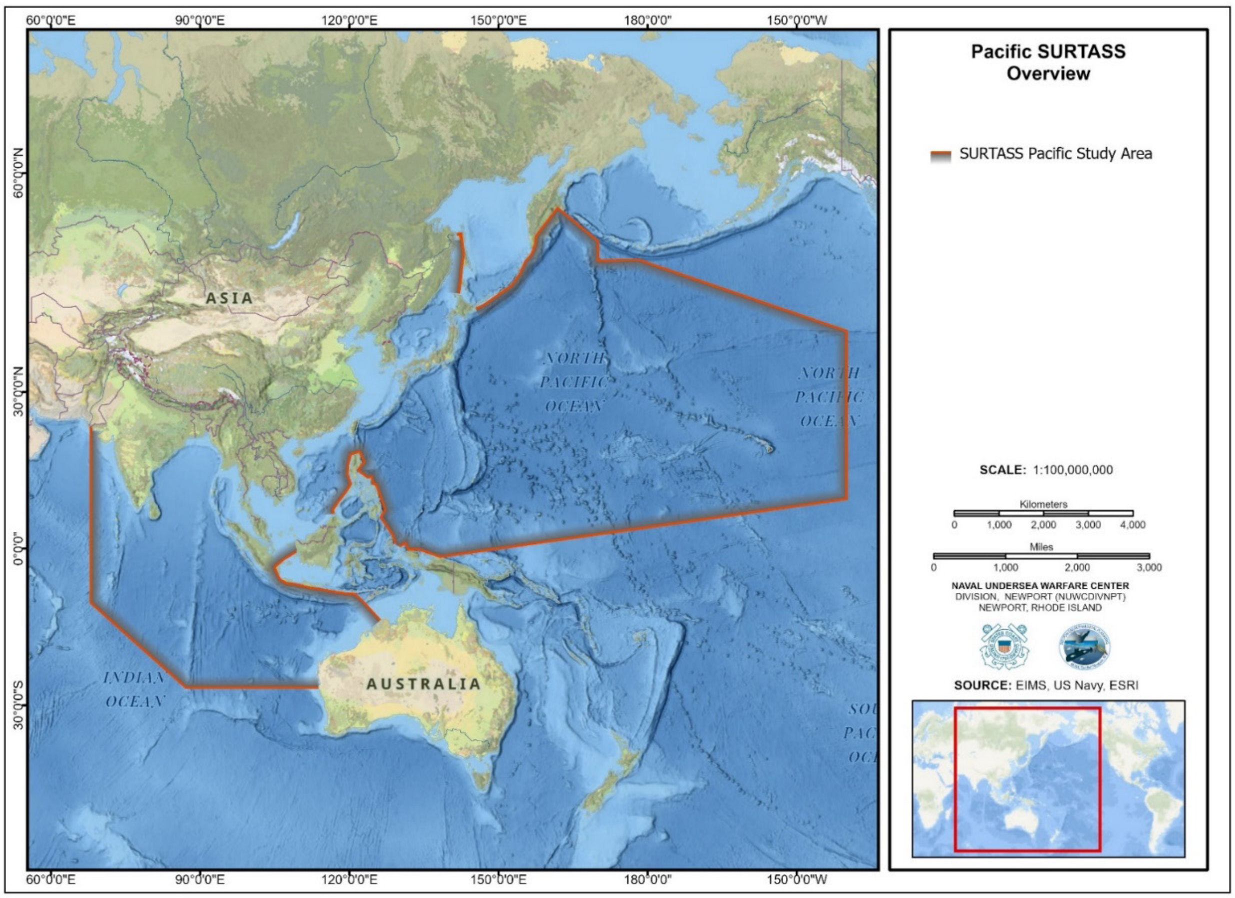

Figure 2-1. Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) Sonar Training and Testing Study Area

Table 2-1. Presence of each species in the Surveillance Towed Array Sensor System (SURTASS) Low Frequency Active (LFA) Sonar Training and Testing Study Area

Species Name	Common Name	Surrogate Species	Section
Cetaceans			
Family: Balaenopteridae			
Balaenoptera acutorostrata	Common minke whale	N/A	2.2.1.1.1
Balaenoptera bonaerensis	Antarctic minke whale	N/A	2.2.1.1.2
Balaenoptera borealis	Sei whale	Bryde's whale (*Balaenoptera edeni*)	2.2.1.1.3
Balaenoptera edeni	Bryde's whale	N/A	2.2.1.1.4
Balaenoptera musculus	Blue whale/Pygmy blue whale	N/A	2.2.1.1.5
Balaenoptera omurai	Omura's whale	Bryde's whale (*Balaenoptera edeni*)	2.2.1.1.6
Balaenoptera physalus	Fin whale	N/A	2.2.1.1.7
Eubalaena japonica	North Pacific right whale	North Atlantic right whale (*Eubalaena glacialis*)	2.2.1.1.8
Megaptera novaeangliae	Humpback whale	N/A	2.2.1.1.9
Family: Delphinidae			
Delphinus delphis	Common dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.1
Feresa attenuata	Pygmy killer whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.2
Globicephala macrorhynchus	Short-finned pilot whale	N/A	2.2.1.2.3
Grampus griseus	Risso's dolphin	N/A	2.2.1.2.4
Lagenodelphis hosei	Fraser's dolphin	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.2.5

Species Name	Common Name	Surrogate Species	Section
Lagenorhynchus obliquidens	Pacific white-sided dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.6
Lissodelphis borealis	Northern right whale dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.7
Neophocaena phocaenoides	Indo-Pacific finless dolphin	N/A	2.2.1.2.8
Orcaella brevirostris	Irrawaddy dolphin	N/A	2.2.1.2.9
Orcinus orca	Killer whale	N/A	2.2.1.2.10
Peponocephala electra	Melon-headed whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.11
Pseudorca crassidens	False killer whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.12
Sousa chinensis	Indo-Pacific humpback dolphin	N/A	2.2.1.2.13
Stenella attenuata	Pantropical spotted dolphin	N/A	2.2.1.2.14
Stenella coeruleoalba	Striped dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.15
Stenella longirostris	Spinner dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.16
Steno bredanensis	Rough-toothed dolphin	N/A	2.2.1.2.17
Tursiops aduncus	Indo-Pacific bottlenose dolphin	N/A	2.2.1.2.18
Tursiops truncatus	Common bottlenose dolphin	N/A	2.2.1.2.19
Family Eschrichtiidae			
Eschrichtius robustus	Gray whale	N/A	2.2.1.3.1
Family: Kogiidae			
Kogia breviceps	Pygmy sperm whale	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.4.1

Species Name	Common Name	Surrogate Species	Section
Kogia sima	Dwarf sperm whale	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.4.2
Family: Phocoenidae			
Phocoenoides dalli dalli and *Phocoenoides dalli truei*	Dall's porpoise	N/A	2.2.1.5.1
Phocoena phocoena	Harbor porpoise	N/A	2.2.1.5.2
Family: Physeteridae			
Physeter macrocephalus	Sperm whale	N/A	2.2.1.6.1
Family: Ziphiidae			
Berardius bairdii	Baird's beaked whale	Goose-beaked whale (*Ziphius cavirostris*)	2.2.1.7.1
Indopacetus pacificus	Longman's beaked whale	Blainville's beaked whale (*Mesoplodon densirostris*)	2.2.1.7.2
Mesoplodont whale guild *Mesoplodon* spp. *(M. carlhubbsi, M. densirostris, M. ginkogodens, M. hotaula, M. stejnegeri, M. traversii)*	Hubb's, Blainville's, Ginkgo-toothed, Deraniyagala's, Stejneger's, Spade-toothed beaked whales	Blainville's beaked whale (*Mesoplodon densirostris*)	2.2.1.7.3
Mesoplodon densirostris	Blainville's beaked whale	N/A	2.2.1.7.4
Ziphius cavirostris	Goose-beaked whale	N/A	2.2.1.7.5
Carnivores			
Family: Mustelidae			
Enhydra lutris kenyoni	Northern sea otter	N/A	2.2.2.1.1
Family: Otariidae			
Callorhinus ursinus	Northern fur seal	N/A	2.2.2.2.1
Eumetopias jubatus	Steller sea lion	N/A	2.2.2.2.2
Family: Phocidae			
Erignathus barbatus	Bearded seal	N/A	2.2.2.3.1
Histriophoca fasciata	Ribbon seal	N/A	2.2.2.3.2
Monachus schauinslandi	Hawaiian monk seal	N/A	2.2.2.3.3

Species Name	Common Name	Surrogate Species	Section
Phoca hispida	Ringed seal	N/A	2.2.2.3.4
Phoca largha	Spotted seal	Harbor seal (*Phoca vitulina*)	2.2.2.3.5
Phoca vitulina	Harbor seal	N/A	2.2.2.3.6
Sirenians			
Family: Dugongidae			
Dugong dugon	Dugong	N/A	2.2.3.1.1

2.2 MARINE MAMMAL DIVE BEHAVIOR SUMMARIES

This section discusses the depth distributions that were constructed for each species, surrogate species, or guild based on the best available science. Ideally, depth distributions would be specific to different locations; however, in most cases, diving data were not available for the precise locations within the SURTASS LFA Sonar Training and Testing Study Area. Marine mammal dive behaviors are not easily stereotyped, but a species' behavior can generally be quantified by using an average percentage of time that an animal will typically spend within a range of depths, or depth bin. For each species, a distribution throughout the water column is presented, along with a list of references that are the source of the data and an explanation about how these references were used to create the distribution. Depth bins are given in meters (m). Depending on the species, the distribution may cover a larger or smaller range of depths, such as for a shallow diving fur seal or a deep diving sperm whale. Likewise, depth bins may be smaller near the surface or larger at greater depths (e.g., 20-m bins near the surface where the animal spends more time or 100-m bins at the deepest depths the animal can reach). For certain species (e.g., the humpback whale), more than one depth distribution is given due to documented differences in diving behavior (e.g., while foraging or breeding). Individual species are listed within each order.

2.2.1 Cetaceans

2.2.1.1 Family Balaenopteridae

2.2.1.1.1 *Balaenoptera acutorostrata*, Common Minke Whale

Common minke whales are widely distributed throughout the world oceans, occurring in coastal and continental shelf waters, the deeper waters along continental slopes, and further seaward (Dorsey et al. 1990; Øien 1990). Fish (e.g., capelin, sandlance, and herring) and planktonic crustaceans (e.g., krill) are the main components of the common minke whale diet (Haug et al. 1995). Common minke whales feed by side-lunging into schools of prey as well as gulping large amounts of water (Jefferson et al. 2008; Stimpert et al. 2014).

Little data have been collected on the dive behavior of common minke whales. In order to build a representative depth distribution for common minke whales, data from Figure 2 in Blix and Folkow (1995) were used. Blix and Folkow (1995) presented a time-depth record for a single common minke whale tagged off the west coast of Svalbard, a Norwegian archipelago. This animal was predominantly foraging between 25 and 50 m. Two depth bins and the time spent within each depth bin were estimated, with the resulting depth distribution shown. The depth distribution data are derived from a short (75-min) dive profile of a single animal, in which two behaviors are represented: cruising (52 percent of time) and foraging (48 percent of time). However, the amount of time spent in these two behaviors can vary significantly among individuals (Blix and Folkow 1995). The depth distribution for common minke whales is given in Table 2-2.

Table 2-2. Percentage of time at depth for the common minke whale[1]

Depth Bin (m)	% of Time at Depth
0–25	79.7
25–65	20.3

[1] Based on data from Blix and Folkow (1995).

More recent data suggest that the common minke whale can dive to greater depths than depicted by this distribution. For example, common minke whales in the Antarctic have been associated with krill patches found at a median depth of 118 m (Friedlaender et al. 2009b), and two tagged whales were recorded to dive to a maximum depth of 105 m (Stimpert et al. 2014). The mean dive depth for the tagged whales in Antarctica was 18 m (Stimpert et al. 2014). Off Scotland, common minke whales were found where patches of pre-spawning herring occur at depths between 100 and 150 m (MacLeod et al. 2003b), while off the coast of California, tagged common minke whales dove to 130 m (Southall et al. 2014), although in both cases whales spent the majority of their time in the top 25 m of the water column. There is also limited evidence that minke whales may exhibit diurnal variation in diving behavior (Joyce et al. 1990; Stockin et al. 2001). Christiansen et al. (2015) did not tag common minke whales but did observe their surfacing patterns during different activities. Surface foraging, near-surface foraging, deep foraging, traveling, and resting were observed. The depth distribution shown in Table 2-2 is considered representative for common minke whales until more information becomes available.

2.2.1.1.2 *Balaenoptera bonarensis*, Antarctic Minke Whale

The Antarctic minke whale is considered primarily a Southern Hemisphere species, occurring in both coastal and offshore regions from about 7 degrees south to the ice edges of Antarctica (Jefferson et al. 2015). This species has also been observed and recorded in sub-tropical waters of the South Atlantic, South Pacific, and Indian Ocean during winter (Cerchio et al. 2018; McCauley et al. 2004). There appears to be a general northward shift in winter for breeding, but many individuals are known to occur year-round in the Antarctic. Antarctic minke whales feed on krill in sea-ice environments (Friedlaender et al. 2014). These whales lunge feed or periodically gulp large amounts of water filled with prey (e.g., krill, phytoplankton, small fish) (Ainley et al. 2020; Friedlaender et al. 2014; Goldbogen et al. 2012).

To build a representative depth distribution for Antarctic minke whales, data from Table 1 and extrapolations from the text of Friedlander et al. (2014) and Figure 1 in Risch et al. (2014) were used. Together, these studies reported the dive behavior from four tagged Antarctic minke whales in Wilhelmina Bay, Antarctic Peninsula. Friedlander et al. (2014) presented a time-depth profile over an 18-hour period. Risch et al. (2014) presented complete dive profiles for durations of 18 and 8 hours. Data from both papers will be used as a proxy for percentage of time at depth. The depth distribution for Antarctic minke whales is given in Table 2-3.

Table 2-3. Percentage of time at depth for the Antarctic minke whale[1]

Depth Bin (m)	% of Time at Depth
0–10	52.25
11–20	19.2
21-30	10.7
31-40	6.9
41-50	4.3
51-60	2.9
61-70	1.6
71-80	1.1
81-110	1.05

[1] Based on data from Friedlander et al. (2014) and Risch et al. (2014).

Although other studies did not include usable depth distributions for Antarctic minke whales, they did provide additional information to categorize dive behavior. Antarctic minke whales dove for durations between 9.7 and 10.8 min, with long dives separated by 1.3 to 3.5 min of shallow submergence or surface "rafting" (Leatherwood et al. 1981). Gales et al. (2013) found that two Antarctic minke whales in Wilhelmina Bay, Ross Sea, foraged at an average depth of 19 m (maximum of 106 m) for an average of 1.5 min (maximum of 9.4 min). Non-foraging dive depths reached maximum depths of over 350 m (Gales et al. 2013). Ainley et al. (2020) found that one tagged Antarctic minke whale in McMurdo Sound, Ross Sea, dove for the majority of its time underwater to the range in which their food sources were found. The authors found that the Antarctic minke whale consistently dove to a mean depth of 72 m with 90 percent of all dives to depths of 19 to 130 m (Ainley et al. 2020). These dive depths largely fall into the depth bins presented in the representative dive profile, though Ainley et al. (2020) and Gales et al. (2013) found deeper maximum depths than presented in Table 2-3.

2.2.1.1.3 *Balaenoptera borealis*, Sei Whale

Sei whales have a cosmopolitan distribution, migrating between high-latitude feeding grounds and low-latitude breeding grounds (Horwood 2002). They have been found on the outer edge of the continental slope in waters 500 to 2,250 m deep (Baines and Reichelt 2014). Sei whales are capable of diving for between 5 and 20 min (Reeves et al. 2002) to feed on plankton, predominantly copepods and euphausiids, which occur between the surface and depths around 150 m (Baines and Reichelt 2014; Budylenko 1978; Flinn et al. 2002). They may also feed on small schooling fish and cephalopods by both gulping and skimming.

Little data have been collected on the dive behavior of sei whales. Sei whales are not thought to be deep divers. Baumgartner et al. (2011) found that sei whales were absent during times when copepods were at depth, suggesting that sei whales may only be able to feed effectively on copepod aggregations when they are at or near the surface. In addition, Baumgartner and Fratantoni (2008) observed low calling rates during the night when copepods were at the surface, and higher calling rates during the day when copepods were at depth. This study speculated that sei whales reduced calling rates to accommodate nighttime feeding on the copepod aggregations at the surface and increased calling rates during the day when copepods migrated to deeper depths where they were unavailable as prey to the sei whales. Ishii et al. (2017) also found that sei whale behavior varied based on the depth copepod aggregations were found. Two sei whales were tagged in this study, and one individual showed significantly deeper dives during the daytime when food sources were at greater depths, which refutes the idea that sei whales are not migrating to deeper depths to track food sources. As with other studies, whales were found in shallow water (10 m) with copepods after sunset (Ishii et al. 2017).

Due to a lack of available data on the dive behavior of sei whales, they will be represented by a surrogate species: the Bryde's whale (Section 2.2.1.1.4). The Bryde's whale is the closest relative to the sei whale (Sasaki et al. 2005); these species are of similar body size (Horwood 2002) and feed on similar prey in the Northern Hemisphere (Flinn et al. 2002; Mizroch et al. 1984). Although sei whales differ from other Balaenopterids in their prey preference for copepods, this preference means that, like Bryde's whales, sei whales are not thought to be deep divers, spending most of their time near the surface (Alves et al. 2010). Foraging sei whales and Bryde's whales utilize similar water depths (Alves et al. 2010; Baumgartner et al. 2011). In Ishii et al. (2017), where sei whales were hypothesized to follow migrating copepods, two tagged sei whales were recorded diving to average foraging depths of 14.2 and 17.9 m, with the deepest foraging depth recorded at 48 and 57 m, respectively (Ishii et al. 2017). This falls within the range of behavior depicted in the Bryde's whale dive profile in Table 2-4.

2.2.1.1.4 *Balaenoptera edeni*, Bryde's Whale

Bryde's whales are found in tropical and temperate waters, with separate coastal and offshore forms (Best 2001; Weir 2007). There is ongoing debate about the taxonomic relationship between two morphotypes—the larger -*brydei* form and the smaller -*edeni* form (Sasaki et al. 2006b). These two forms are genetically distinct and are differentiated by geographic distribution, inshore/offshore habitat preferences, and size. However, for both morphotypes, which are not easily distinguished at sea, the scientific name *B. edeni* is commonly used. The offshore Bryde's whale occurs globally in pelagic waters, while the Eden's whale typically occurs in nearshore waters of the Pacific and Indian Oceans (Rice 1998). Both subspecies occur within the SURTASS LFA Sonar Training and Testing Study Area (Cooke and Brownell Jr 2018; De Boer et al. 2003). The main prey of Bryde's whales includes pelagic schooling fish species, such as sardines, mackerel, and herring (Siciliano et al. 2004), as well as cephalopods and small crustaceans (Kato 2002; Omura 1962).

To build a representative depth distribution for Bryde's whales, data from Table 1 in Alves et al. (2010) were used. Alves et al. (2010) reported a distribution of time spent in shallow versus deep dives for two whales tagged with a time-depth recorder near Madeira Island, Spain. Though these data are not strictly an indication of time spent in the two different depth bins (time spent diving down to 40 to 292 m includes time passing through the 0- to 40-m depth bin), the data are the best available approximation of time spent at depth. The depth distribution for Bryde's whales is given in Table 2-4.

Table 2-4. Percentage time at depth for the Bryde's whale[1,2]

Depth Bin (m)	% of Time at Depth
0–40	84.7
40–292	15.3

[1] Based on data from Alves et al. (2010).

[2] This depth distribution is also representative of Omura's whale and the sei whale.

Little other data have been collected on the dive behavior of Bryde's whales. Dong et al. (2022) tagged one Bryde's whale off the coast of China, tracking the whale's movements for 6 hours. The depth of the area in which this whale occurred was 8 to 10 m. In this shallow area, the Bryde's whale spent roughly 11 percent of its time on the water's surface (less than 0.5 m) and 89 percent of its time diving (Dong et al. 2022).

2.2.1.1.5 *Balaenoptera musculus*, Blue Whale/Pygmy Blue Whale

Blue whales have a cosmopolitan distribution, living in both coastal and offshore waters (Jefferson et al. 2008). Blue whales track the diel vertical migration of their prey and feed almost exclusively on euphausiids, or krill (Sears 2002). Although surface feeding has been observed during the daylight, it is more usual for blue whales to dive to at least 100 m into layers of euphausiid concentrations during daylight hours and feed nearer the surface at night (Sears and Perrin 2008).

To build a representative depth distribution for blue whales, data from Figures 4 and 8 in Oleson et al. (2007) as well as data from Figure 2 from Acevedo-Gutiérrez et al. (2002) were used. Oleson et al. (2007) provided graphs in Figure 8 of the percentage of time at depth of 38 blue whales off the coast of California. The data for the non-vocal, AB callers, and D callers were averaged together to get a general depth distribution. However, the percentage of time at the surface was ignored by this study. By incorporating the average number of surfacing events over time in the sample dive profile from Figure 4 in Oleson et al. (2007) and the average time spent at surfacing events from Figure 2 in the Acevedo-Gutiérrez et al. (2002) study, a percentage of time spent in the surface bin could be estimated (20.9 percent). The remaining bins from the Oleson et al. (2007) study were redistributed proportionally to account for the remaining 79.1 percent of the time. The depth distribution for blue whales is given in Table 2-5.

Table 2-5. Percentage of time at depth for the blue whale[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–5	21.2	155–165	2.2
5–15	12.7	165–175	2.3
15–25	9.9	175–185	2.2
25–35	6.4	185–195	2.2
35–45	5.3	195–205	1.4
45–55	4.0	205–215	1.1
55–65	3.5	215–225	1.1
65–75	2.8	225–235	1.0
75–85	2.2	235–245	0.9
85–95	2.4	245–255	0.7
95–105	2.1	255–265	0.7
105–115	2.1	265–275	0.3
115–125	2.0	275–285	0.2
125–135	2.1	285–295	0.2
135–145	2.1	295–305	0.2
145–155	2.3	305–315	0.2

[1] Based on data from Oleson et al. (2007) and Acevedo-Gutiérrez et al. (2002).

Although other studies did not include depth distributions for blue whales, they did provide additional information to categorize dive behavior. Mate et al. (2016) noted that blue whale dive profiles often recorded stereotypical upward excursions during the bottom phase of the dive, which are known to indicate feeding lunges (Calambokidis et al. 2008; Croll et al. 2001; Fahlbusch et al. 2022). Blue whales in the Gulf of St. Lawrence conducted foraging dives to 150 m, where feeding lunges were observed (Doniol-Valcroze et al. 2011). Similarly, a study conducted in Monterrey Bay found that blue whales fed on the most concentrated patches of krill at depths of 130 to 150 m (Schoenherr 1991). Blue whales off central California foraged at depths between 130 and 300 m (Calambokidis et al. 2008; Croll et al. 2001; Fahlbusch et al. 2022), while in southern California, dive depths ranged from 50 to 350 m (Acevedo-Gutiérrez et al. 2002; Croll et al. 2001; De Vos et al. 2012; Goldbogen et al. 2012; Goldbogen et al. 2013; Mate et al. 2016; Oleson et al. 2007; Southall et al. 2014). Seven whales tagged off the coast of southern California dove to a mean depth of 140 m and a maximum depth of 204 m during foraging, while to only a mean depth of 67.6 m during non-foraging dives (Croll et al. 2001). These data are consistent with the depth distribution in Table 2-5.

2.2.1.1.6 *Balaenoptera omurai*, Omura’s Whale

Omura’s whales were described and differentiated from Bryde’s whales via genetic analysis in the early 2000s (Sasaki et al. 2006a; Wada et al. 2003) and recognized alive in the wild in 2015. The primary range of Omura’s whale is considered the tropical and subtropical waters of the western Pacific and eastern Indian Oceans, and Omura’s whale tends to occur in nearshore waters over the continental shelf (Jefferson et al. 2015). Little is known about the distribution of Omura’s whales, but there is a year-round (non-migrating) population off the coast of Madagascar (which is outside of the SURTASS LFA Sonar Training and Testing Study Area) (Cerchio et al. 2015).

Due to a lack of available data on the dive behavior of Omura's whales, they will be represented by a surrogate species: the Bryde's whale (Section 2.2.1.1.4). The Bryde's whale looks very similar to the Omura's whale, as they are both small rorquals that lunge feed on schooling fish and krill in tropical habitats (Cerchio et al. 2019). Swim speeds and dive behavior of Omura's whales have not yet been documented; therefore, the surrogate will be used. The depth distribution for Bryde's whales can be found in Table 2-4.

2.2.1.1.7 *Balaenoptera physalus*, Fin Whale

The fin whale occurs in greatest concentrations in cold and temperate waters around the globe, and are commonly found seaward of the continental slope (Aguilar 2002). Prey species include euphausiids (Laidre et al. 2010; Ruchonnet et al. 2006; Vikingsson 1997), schooling fish such as herring and capelin (Nøttestad et al. 2002b), and cephalopods (Flinn et al. 2002). A 2001 study has shown that dense prey concentrations are typically found at depths greater than 100 m off the coast of California (Croll et al. 2001).

To build a representative depth distribution for fin whales, data from Figure 4a in Croll et al. (2001) and the text of Goldbogen et al. (2006) were used. Due to the lack of data on time spent at depth, the data from Croll et al. (2001) will be used as a proxy for the percentage of time spent at depth. Croll et al. (2001) found that, amongst the 15 tagged fin whales, there was a maximum dive depth of 316 m. Foraging dives were deeper and longer in duration than non-feeding dives. Goldbogen et al. (2006) reported that tagged whales spent 40 percent of time in the top 50 m. Time spent at depths below 50 m was extracted from dive profiles presented in Croll et al. (2001) to represent the remaining 60 percent of time. The depth distribution for fin whales is given in Table 2-6.

Table 2-6. Percentage of time spent at depth for the fin whale[1]

Depth Bin (m)	% of Time at Depth
0–50	40
50–70	13.9
70–90	9.6
90–110	8.1
110–130	11.4
130–150	8.4
150–170	3.5
170–190	2.0
190–210	1.4
210–230	0.6
230–250	0.6
250–270	0.2
270–290	0.1
290–310	0.2

[1] Based on data from Croll et al. (2001) and Goldbogen et al. (2006).

Although other studies did not include depth distributions for fin whales, they did provide additional information to categorize dive behavior. Off southern California, foraging dives of 100 to 300 m (Acevedo-Gutiérrez et al. 2002; Goldbogen et al. 2006; Mate et al. 2016) have been recorded. Although dive depths of 350 m were recorded off the coast of southern California (Mate et al. 2016). Southall et al. (2014) reported that dives by fin whales rarely exceeded 250 m. Meanwhile, foraging dives off the coast of Alaska had a grand mean depth of 115 m (Witteveen et al. 2015) and in the Ligurian Sea, a maximum dive to over 470 m was noted (Panigada et al. 1999). Fonseca et al. (2022) measured whale dives off of the Azores and noted the diel pattern of behavior and dive type. These data are mostly consistent with the depth distribution in Table 2-6.

2.2.1.1.8 *Eubalaena japonica*, North Pacific Right Whale

The North Pacific right whale is now considered one of the rarest species of marine mammal (Wade et al. 2011). Based on whaling records and genetic analyses, there appears to be two separate populations of North Pacific right whales: an eastern population (with summer feeding grounds primarily in the southeastern Bering Sea) and a western population (with summer feeding grounds primarily in the Sea of Okhotsk) (Brownell et al. 2001). The winter calving grounds of both populations remain largely unknown. Rare occurrences of North Pacific right whales have been documented in the waters of the Gulf of Alaska, Sea of Japan (off Republic of Korea), and North Pacific waters, which includes around the Ogasawara and Kuril Islands; around Hokkaido, Japan; and offshore of Kamchatka, Russia (Jefferson et al. 2015; Sekiguchi et al. 2014). North Pacific right whales forage on zooplankton (e.g., copepods, euphausiids, and cyprids) by skimming the surface of the water with their mouths open (Baumgartner et al. 2013). Little data have been collected on the dive behavior of North Pacific right whales. Crance et al. (Crance et al. 2017a); Crance et al. (2017b) recorded dive durations ranging from 41 seconds (sec) to 12 min. North Pacific right whale vocalization has been recorded at depths up to 25 m, suggesting that whales dive to these depths (Thode et al. 2017).

Due to a lack of available data on the dive behavior of North Pacific right whales, they will be represented by a surrogate species: the North Atlantic right whale. These whales are in the same family and utilize the same zooplankton feeding strategies in northern latitudes identified as foraging grounds. As the North Atlantic right whale is not present in the SURTASS LFA Sonar Training and Testing Study Area, a full description of the dive profile for this species is detailed below and in Table 2-7.

To build a representative depth distribution for the North Atlantic right whale on foraging grounds, depth distributions for 46 whales from the Bay of Fundy were provided by D. Nowacek and A. McGregor (2010). The Bay of Fundy data reflect skim feeding both at the surface and at depth (Nowacek and McGregor 2010). Parks et al. (2011) examined dive behavior during the spring feeding season in Cape Cod Bay (Parks et al. 2011). Parks et al. (2011) reported whales spent on average 84 percent of their time within 3 m of the surface, while Nowacek and McGregor (2010) reported whales spent on average 32.89 percent of their time in the top 10 m. The average of these percentages amounts to 58.45 percent of the whales' time spent in the surface bin (0–10 m). The remaining depth bins provided by Nowacek and McGregor (2010) were redistributed proportionally to account for the remaining 41.56 percent of time. The resulting depth distribution for right whales on foraging grounds is given in Table 2-7.

Table 2-7. Percentage of time at depth for the North Atlantic right whale on foraging grounds[1,2]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	58.45	110–120	5.19
10–20	2.39	120–130	4.79
20–30	1.66	130–140	3.88
30–40	1.22	140–150	3.31
40–50	2.08	150–160	1.94
50–60	1.07	160–170	0.84
60–70	0.97	170–180	0.28
70–80	2.29	180–190	0.02
80–90	2.33	190–200	0.02
90–100	2.62	200–210	0.01
100–110	4.65	210–220	0.01

[1]Based on data from Nowacek and McGregor (2010) and Parks et al. (2011).
[2]This depth distribution is representative of the North Pacific right whale.

2.2.1.1.9 *Megaptera novaeangliae*, Humpback Whale

Humpback whales have a cosmopolitan distribution in the coastal and continental shelf waters of the globe. They migrate between mid- to high-latitude foraging grounds and low-latitude breeding grounds (Clapham 2002). Humpback whales feed on a variety of organisms, including euphausiids and small schooling fish (Hain et al. 1982; Hazen et al. 2009; Laerm et al. 1997; Witteveen et al. 2015).

Due to a separation of behaviors based on location within a foraging ground or within a breeding ground, two separate representative depth distributions were compiled for humpback whales. To build a representative depth distribution for humpback whales on foraging grounds, data from Dietz et al. (2002) were used—from both the text and Figure 3.8. Dietz et al. (2002) shows the number of dives per hour to specific depth bins. The data from Dietz et al. (2002) will be used as a proxy for the percentage of time spent at depth for the six whales tagged off the foraging grounds of West Greenland. Although Figure 3.8 from Dietz et al. (2002) begins at a depth of 8 m, the text states that the average time spent at the surface is 83.3 percent during mid-day and 75 percent at midnight, resulting in an average surface time of 79.2 percent. The data from Dietz et al. (2002) were then redistributed proportionally to account for the remaining 20.8 percent of time. The depth distribution for humpback whales on foraging grounds is given in Table 2-8.

Table 2-8. Percentage of time at depth for the humpback whale on foraging grounds[1]

Depth Bin (m)	% of Time at Depth
0–8	79.2
8–20	11.65
20–35	2.70
35–50	1.04
50–100	1.56
100–150	1.56
150–200	1.25
200–300	0.935
300–400	0.105

[1] Based on data from Dietz et al. (2002).

Although other studies did not include depth distributions for humpback whales, they did provide additional information to categorize dive behavior on feeding grounds. Dive depths on the Greenland foraging grounds (Dietz et al. 2002) are consistent with the depth of feeding reported by Simon et al. (2012) off Greenland, Stimpert et al. (2012) off Antarctica, Goldbogen et al. (2008) off central California, and Witteveen et al. (2015) and Dolphin (1987a) off Alaska. However, Dolphin (1987b) reported that 75 percent of feeding dives were to less than 60 m, and Friedlaender et al. (2009a) found evidence of bottom feeding in the shallower water (less than 50 m) of the Gulf of Maine. Although the depth distribution in Table 2-8 has a maximum depth of 400 m, over 95 percent of the time is in the top 50 m. Therefore, the depth distribution in Table 2-8 is consistent with these studies as well.

Humpback whales have major breeding grounds in several locations, including the West Indies, Hawaii, Mexico, and Japan (Clapham 2002). To build a representative depth distribution for humpback whales on breeding grounds, data from Table 3 in Baird et al. (2000) were used. Baird et al. (2000) reported the time at depth data for 10 whales in Hawaiian waters. Although all 10 whales were thought to be males, the whales were engaged in a variety of behaviors, including escorting females and calves. Therefore, the depth distribution in Table 2-9 represents the best estimate of time spent at depth by whales on a breeding ground. Baird et al. (2000) found that, on average, about 40 percent of a whale's time was spent in the top 10 m and about 90 percent of the time was spent in the top 100 m. The depth distribution for humpback whales on breeding grounds is given in Table 2-9.

Table 2-9. Percentage of time at depth for the humpback whale on breeding grounds[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	39.65	90–100	1.55
10–20	26.51	100–110	1.39
20–30	11.65	110–120	1.31
30–40	4.25	120–130	0.92
40–50	3.04	130–140	0.72
50–60	2.47	140–150	0.30
60–70	2.14	150–160	0.23
70–80	1.66	160–170	0.15
80–90	1.97	170–180	0.19

[1] Based on data from Baird et al. (2000).

Although other studies did not include depth distributions for humpback whales, they did provide additional information to categorize dive behavior on breeding grounds. Dive depths on the Hawaiian breeding grounds are mostly consistent with dive depths and percentage of time at depth reported by Derville et al. (2020) for males and mother-calf pairs off New Caledonia, and as reported by Stimpert et al. (2012) for calves under 6 months of age. Huetz et al. (2022) tagged 29 calves of different age classes and found that calves increased the duration of their dives with age. Mother-calf pairs in this study showed high levels of synchrony (Huetz et al. 2022). Derville et al. (2020) reported that whales left the breeding grounds and traveled into pelagic waters where there were seamounts during the breeding season and during early migration stages.

2.2.1.2 Family Delphinidae

2.2.1.2.1 *Delphinus delphis*, Common Dolphin

Although species of common dolphins are sympatric in some nearshore continental shelf waters, common dolphins are typically found in deeper waters along the continental slope (Cañadas and Hammond 2008; Heyning and Perrin 1994; Jefferson et al. 2009; Rosel et al. 1994; Selzer and Payne 1988). They feed on epipelagic and mesopelagic fish and squid (Selzer and Payne 1988), and also forage at night on vertically-migrating prey associated with the deep scattering layer (Evans 1994; Neumann and Orams 2003; Ohizumi et al. 1998; Pusineri et al. 2007).

Little data have been collected on the dive behavior of the common dolphin. Evans (1975; 1994) described the late afternoon and evening diving behavior of an adult female common dolphin in the Pacific Ocean. Before 1730, the dolphin mostly remained in the top 10 m, at which time it switched to a pattern of regular dives to 50 m, with a maximum dive depth of just over 200 m (Evans 1974, 1994).

Due to the lack of available data on the diving behavior of the common dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.14). Pantropical spotted dolphins also make shallower dives during the day than at night, when they forage on vertically-migrating prey associated with the deep scattering layer (Scott and Chivers 2009). During the day, pantropical spotted dolphins spend 94 percent of their time in the top 20 m of the water column, while at night 95 percent of their time is spent in the top 50 m (Baird et al. 2001). Evans (1994) reported the maximum dive depth for three common dolphins was 257 m. Similarly, maximum dive depths for pantropical spotted dolphins are 122 m for daytime and 213 m for nighttime (Baird et al. 2001). Pantropical spotted dolphins and common dolphins are members of the same subfamily, Delphinidae (LeDuc et al. 1999), and their behavior shows clear similarities in diving pattern, foraging behavior, and water column usage. The depth distribution of the common dolphin is given in Table 2-16.

2.2.1.2.2 *Feresa attenuata*, Pygmy Killer Whale

Pygmy killer whales inhabit tropical and subtropical waters of the continental slope and waters farther offshore (Donahue and Perryman 2002). Analyses of their stomach contents indicate that their primary prey consists of cephalopods and fish, although other marine mammals also constitute some portion of their diet (Mignucci-Giannoni et al. 1999; Perryman and Foster 1980). Some shallow-water prey (from less than 200 m deep) have been reported in the stomachs of stranded pygmy killer whales, though these prey species may have been consumed as animals moved closer to shore prior to stranding (Sekiguchi et al. 1992; Zerbini and de Oliveira Santos 1997). Characteristics of their echolocation clicks indicate that pygmy killer whales could detect fish and cephalopod prey at distances of 50 to 200 m (Madsen et al. 2004b).

Pygmy killer whales were found around the Island of Hawaii in coastal waters as shallow as 6 m and offshore waters as deep as 3,000 to 5,000 m (Baird et al. 2017; McSweeney et al. 2009). In recent years, data have been collected on the dive behavior of pygmy killer whales from a limited number of individuals. Pulis et al. (2018) tagged two adult males in the Gulf of America, and found that 96 percent of the dives occurred at night in waters 200 to 1,200 m deep (Pulis et al. 2018). The average dive depth was 127.5 m, and the deepest dive reached 368 m (Pulis et al. 2018). The dive depths in this study fall within the range of the surrogate species, the Risso’s dolphin (Table 2-11). These pygmy killer whales spent 26.8 percent of the recorded time at depths greater than or equal to 30 m (Pulis et al. 2018), which is likely slightly less than their surrogate species, the Risso’s dolphin.

Due to a limited sample size (two individuals) and the lack of additional data on the dive behavior of pygmy killer whales, they will be represented by a surrogate species: the Risso’s dolphin (Section 2.2.1.2.4). The closest relatives to the pygmy killer whale for which diving behavior has been studied are three members of the subfamily Globicephalinae: the short-finned pilot whale, the long-finned pilot whale, and the Risso’s dolphin (LeDuc et al. 1999). Risso’s dolphins and pygmy killer whales have both been placed in the Globicephalinae family (Vilstrup et al. 2011). The pygmy killer whale (at 2.3 m long) is closer in size to Risso’s dolphins (4 m) than to the pilot whales (6 m). Both pygmy killer whales and Risso’s dolphins are found in deep water and feed on squid and other cephalopods. The depth distribution for the pygmy killer whale can be found in Table 2-11.

2.2.1.2.3 *Globicephala macrorhynchus*, Short-Finned Pilot Whale

Short-finned pilot whales occur in tropical and warm-temperate waters along the continental shelf and slope (Davis et al. 1998). Short-finned pilot whales feed predominantly on squid, but they also feed on octopus and fish occasionally (Mintzer et al. 2008; Reeves et al. 2002). On the U.S. Pacific coast, the neritic cephalopod, *Loligo* spp., is the dominant prey (Mintzer et al. 2008).

Short-finned pilot whales feed on vertically migrating prey, diving deep during dusk and dawn and staying near the surface at night (Baird et al. 2003).

To build a representative depth distribution for short-finned pilot whales, data from Figure 9 in Wells et al. (2013) were used. Wells et al. (2013) tagged two male pilot whales after a mass stranding event in the Florida Keys. One of the individual tags stopped transmitting after 16 days, but the other tag transmitted for a total of 67 days; thus, the representative depth distribution contains only the Wells et al. (2013) data from the individual with the longer transmission time. Due to the lack of data on time spent at depth, the proportion of dives made to specific depth ranges from Wells et al. (2013) will be used as a proxy for the percentage of time spent at depth. The depth distribution for short-finned pilot whales is given in Table 2-10.

Table 2-10. Percentage of time at depth for the short-finned pilot whale[1,2]

Depth Bin (m)	% of Time at Depth
0–2	32.25
2–50	46.75
50–100	3.00
100–200	5.00
200–300	4.25
300–400	2.75
400–500	1.75
500–600	1.75
600–700	1.75
700–800	0.5
800–900	0.125
900–1,000	0.125

[1] Based on data from Wells et al. (2013).

[2] This depth distribution is also representative of the following species: Fraser's dolphin, pygmy sperm whale, and dwarf sperm whale.

Although other studies did not include depth distributions for short-finned pilot whales, they did provide additional information to categorize dive behavior. In the Mariana Archipelago, Hill et al. (2019) tagged five short-finned pilot whales that dove more often to intermediate depths (101 to 499 m) at twilight and night, suggesting they were targeting vertically migrating prey. The maximum depths recorded in Jensen et al. (2011) were roughly 700 m and recorded in Joyce et al. (2017) were roughly 880 m—hundreds of meters shallower than the maximum depth in Table 2-10. Other studies of tagged whales in the Bahamas (Claridge et al. 2015), the Madeira Islands (Alves et al. 2013), and the Canary Islands (Soto et al. 2008) found similar maximum dive depths as reported above (984 to 1,019 m). Slightly greater dive depths (roughly 1,100 to 1,500 m) were recorded for whales tagged near Cape Hatteras (Adamczak et al. 2021; Quick et al. 2017), the Bahamas (Joyce et al. 2016), and Kaua'i (Baird et al. 2021). Based on the percentage of time at depth in Table 2-10, the total time spent in deeper waters constitutes a very small percentage of the whale's total time. Alves et al. (2013) and Adamczak et al. (2021) support this conclusion.

2.2.1.2.4 *Grampus griseus*, Risso's Dolphin

Risso's dolphins are commonly found in temperate and tropical waters along continental slopes and deep oceanic waters (Azzellino et al. 2008; Baumgartner 1997; Green et al. 1992). Vertically migrating cephalopods are the primary food source for Risso's dolphins (Bearzi and Saylan 2011; Clarke and Pascoe 1985; Soldevilla et al. 2010). Dolphins begin to forage around dusk (Soldevilla et al. 2010; Visser et al. 2021).

To build a representative depth distribution, data from Figure 5 in Wells et al. (2009) were used. Wells et al. (2009) reported on the movement and diving behavior of a rehabilitated adult male Risso's dolphin that stranded on the Gulf Coast of Florida. Due to the method of tag attachment, this animal remained tagged for 23 days, which is the largest dive profile dataset available for a Risso's dolphin. Based on Figure 5 in Wells et al. (2009), the depth distribution for Risso's dolphins was estimated for four 6-hour blocks of time. The tagged animal in this study travelled through waters with a mean depth of 548 m (range 3 to 22,300 m) and was therefore likely not diving close to the seafloor. The deepest dive recorded on the tag was in the 400- to 500-m depth range, and less than 0.1 percent of dives were deeper than 200 m (Wells et al. 2009). The average time spent in these depth bins was calculated for the representative depth distribution. The depth distribution for the Risso's dolphin is given in Table 2-11.

Table 2-11. Percentage of time at depth for the Risso's dolphin[1,2]

Depth Bin (m)	% of Time at Depth
0–1	24.75
1–2	13.5
2–10	16.5
10–50	43.5
50–100	1.1875
100–150	0.1375
150–600	0.425

[1] Based on data from Wells et al. (2009).

[2] This depth distribution is also representative of the following species: pygmy killer whale, false killer whale, and melon-headed whale.

Although other studies did not include usable depth distributions for Risso's dolphin, they did provide additional information to categorize forage dive behavior. Much of the dive information about Risso's dolphins is focused on prey or foraging dolphins (Arranz et al. 2018; Benoit-Bird et al. 2019; Sweeney et al. 2019; Visser et al. 2021). Forage dive depths for Risso's dolphins may not completely align with the dive profile depth distributions because the percentage of time spent traveling and surfacing were not included. Studies differed in the depths at which foraging was centered. These depths may be dependent on the ecology of the foraging location and dive strategy of dolphins (Visser et al. 2021). Risso's dolphins perform deeper dives when spin diving, which occurs when dolphins actively accelerate and rotate while beginning the diving process (Visser et al. 2021). Sweeney et al. (2019) found that 95.6 percent of prey capture events occurred at depths greater than 10 m, and dive depths were clustered between 58 and 78 m

(Sweeney et al. 2019). Table 2-11 indicates that only minimal time is spent between 50 to 600 m, and these depths are where studies indicate that foraging mainly occurs (Benoit-Bird et al. 2019; Sweeney et al. 2019; Visser et al. 2021).

2.2.1.2.5 *Lagenodelphis hosei*, Fraser's Dolphin

Fraser's dolphins are commonly found in the tropics worldwide in waters deeper than 1,000 m. Although they do have occasional strandings in temperate waters, those are thought to be extralimital occurrences (Louella and Dolar 2002; Reeves et al. 2002).

Little data have been collected on the dive behavior of Fraser's dolphins. Robison and Craddock (1983) reported that the mesopelagic fish, shrimp, and squid species that were found in the stomachs of three dolphins typically inhabit depths between 250 and 500 m. Fraser's dolphins in the Sulu Sea, off the coast of the Philippines, were found to feed on vertically migrating species in the upper 200 m of the water column as well as on non-migrating species found at depths below 600 m (Dolar et al. 2003). Fraser's dolphins have also been seen herding fish near the water's surface (Watkins et al. 1994).

Due to the lack of available data on the diving behavior of the Fraser's dolphin, it is represented by a surrogate species: the short-finned pilot whale (Section 2.2.1.2.3). Dolar et al. (1999) found that Fraser's dolphins have myoglobin concentrations consistent with those of other deep-diving marine mammals, and relative muscle masses much greater than those of other dolphins their size, both of which indicate an enhanced diving ability. Therefore, despite their smaller size, the Fraser's dolphin will be modeled using the depth distribution of the short- finned pilot whale, another species in the family Delphinidae that feeds on mesopelagic and bathypelagic prey at similar deep depths (Desportes and Mouritsen 1993; Gannon et al. 1997). The depth distribution for the Fraser's dolphin is given in Table 2-10.

2.2.1.2.6 *Lagenorhynchus obliquidens*, Pacific White-Sided Dolphin

Pacific white-sided dolphins inhabit cold temperate waters of the North Pacific, in both offshore and coastal waters (Becker et al. 2014; Brownell et al. 1999; Waerebeek and Würsig 2002). Their primary prey species include mesopelagic fish and cephalopods as well as epipelagic fish in shallower waters (Brownell et al. 1999; Kajimura and Loughlin 1988; Miyazaki et al. 1991; Morton 2000; Walker and Jones 1994).

Little data have been collected on the dive behavior of the Pacific white-sided dolphin. Hall (1970) trained a captive Pacific white-sided dolphin to dive to a depth of 214 m. However, Black (1994) reported that in coastal waters, 70 percent of dives were shorter than 20 sec in duration, and dives longer than 90 sec were rare, indicating that most dives are shallow. Heise (1997) similarly reported that 70 percent of foraging dives were less than 15 sec in duration. Therefore, Pacific white-sided dolphins are not considered deep divers. This species is thought to feed mostly at night or in the morning (Stroud et al. 1981) when their mesopelagic prey rise to surface waters. In areas where Pacific white-sided dolphins were observed, potential prey was abundant in a shallower layer, at approximately 80 to 90 m depth. Water depth affected the potential prey abundance at all depth layers (0 to 300 m), as potential prey were more abundant in areas with a shallower water depth (Iwahara et al. 2020).

Due to the lack of available data on the diving behavior of the Pacific white-sided dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.14). Pantropical spotted dolphins spend the majority of their time in the top 50 m, and their maximum diving depths are within the range of the dive depth of the trained Pacific white-sided dolphin (Baird et al. 2001; Hall 1970; Scott and Chivers 2009). Pantropical spotted dolphins and Pacific white-sided dolphins also feed on similarly migrating prey species. The depth distribution for the Pacific white-sided dolphin can be found in Table 2-16.

2.2.1.2.7 *Lissodelphis borealis*, Northern Right Whale Dolphin

The northern right whale dolphin is abundant in cold, deep, temperate waters across the North Pacific Ocean (Becker et al. 2014; Forney and Barlow 1998; Jefferson and Newcomer 1993b; Leatherwood and Walker 1979; Rankin et al. 2007). They are known to commonly associate with Pacific white-sided dolphins and Risso's dolphins (Forney and Barlow 1998; Jefferson and Newcomer 1993b), with which they show dietary overlap (Walker and Jones 1994). Northern right whale dolphins near the southern California coast feed principally on cephalopods and a diverse variety of myctophid fish (Jefferson and Newcomer 1993a; Jefferson et al. 1994; Leatherwood and Walker 1979).

Little data have been collected on the dive behavior of the northern right whale dolphin. Some evidence based on stomach contents suggests that northern right whale dolphins may dive as deep as 200 m (Fitch and Brownell 1968; Jefferson et al. 1994). Individual northern right whale dolphins have been observed to dive for brief periods (10 to 75 sec), but can also remain submerged for up to 6.5 min (Cruickshank and Brown 1981; Leatherwood and Walker 1979). Northern right whale dolphins have comparatively low muscle myoglobin content among odontocetes, suggesting they are not deep divers (Noren and Williams 2000).

Due to the lack of available data on the diving behavior of the northern right whale dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.14). Of the two dolphins with which the northern right whale dolphin associates the most, the Risso's dolphin is considered a much deeper diver than the Pacific white-sided dolphin. Because northern right whale dolphins have low muscle myoglobin content and are thought to feed on prey only as deep as 200 m, they are thought to be shallower divers. Therefore, due to dietary similarity and frequent association with the Pacific white-sided dolphin, the northern right whale dolphin will be represented by the same surrogate species, the pantropical spotted dolphin. The depth distribution for the northern right whale dolphin can be found in Table 2-16.

2.2.1.2.8 *Neophocaena phocaenoides*, Indo-Pacific Finless Porpoise

Indo-Pacific finless porpoises occur in shallow tropical to warm temperate coastal marine waters around the northern rim of the Indian and western Pacific Oceans. Finless porpoises prefer shallow, soft-bottomed habitats like bays, mangrove swamps, and estuaries, which are typically less than 50 m deep (Collins et al. 2005; Jefferson et al. 2015; Preen 2004). Adults feed on in-shore, mid-water, and benthic organisms, including teleost fish, shrimp, and cephalopods (Barros et al. 2002; Shirakihara et al. 2008). Calves have been recorded feeding on small fish and cephalopods (Shirakihara et al. 2008).

To build a representative depth distribution, survey data from Figure 4 and textual context in Ali et al. (2023) were used. Ali et al. (2023) reported the depth at which Indo-Pacific finless porpoises were sighted off the west coast of Penang Island, Malaysia. The study calculated the number of porpoises observed within water of different depth ranges and summarized these data with percentages by water depth bins. Because the water depth bins are small (5 m) and these porpoises remain in shallow water, the water depths were used as a proxy for dive depths. Ali et al. (2023) also provided an activity budget. Based on the description of each activity in Ali et al. (2023), it was assumed that the percentage of time that finless porpoises spent in the surface bin included all time spent in milling and resting behaviors. Therefore, this was factored into the depth distribution given in Table 2-12.

Table 2-12. Percentage of time at depth for the Indo-Pacific finless porpoise[1]

Depth Bin (m)	% of Time at Depth
0–5	70.3
5–10	23.5
10–15	5.8
15–200	0.4

[1] Based on data from Ali et al. (2023).

Although other studies did not include depth distributions for Indo-Pacific finless porpoises, one study did provide additional information to categorize dive behavior. De Le Paz et al. (2024) used drones to quantify habitat use of Indo-Pacific finless porpoises in waters around Japan. Indo-Pacific finless porpoises often occurred at depths from 5.5–83.3 m, with 70 percent of sightings occurring in water depths less than 50 m (De la Paz et al. 2024). Beasley and Jefferson (2002) found that Indo-Pacific finless porpoises in Hong Kong's coastal waters spent an average of 60 percent of time near the surface and 40 percent of time performing long dives (30 sec or more). These data are mostly consistent with the depth distribution in Table 2-12.

2.2.1.2.9 *Orcaella brevirostris, Irrawaddy Dolphin*

Irrawaddy dolphins are patchily distributed in coastal, brackish, and fresh waters associated with river mouths of the tropical and subtropical Indo-Pacific (Jefferson et al. 2015). Irrawaddy dolphins are one of only three cetaceans able to inhabit both marine and fresh water (Smith and Jefferson 2002). In marine coastal areas, Irrawaddy dolphins are associated with warm (25 degrees Celsius), shallow (approximately 6 m), and brackish to high-salinity (greater than 20 parts per thousand) waters near river mouths, rarely ranging more than a few kilometers offshore (Minton et al. 2013; Sutaria 2009). Irrawaddy dolphins feed on a variety of prey such as small bony fishes, crustaceans and cephalopods (Baird and Mounsouphom 1997; Jackson-Ricketts et al. 2019; Ponnampalam et al. 2013). Irrawaddy dolphins have been recorded exhibiting foraging behaviors such as circling prey near the surface of water and diving for prey (Casipe et al. 2013; D'Lima et al. 2014; Ponnampalam et al. 2013).

To build a representative depth distribution for the Irrawaddy dolphin, survey data from Figure 4 and textual context in Ali et al. (2023) were used. Ali et al. (2023) reported the depth at which

Irrawaddy dolphins were sighted off the west coast of Penang Island, Malaysia. The study calculated the number of dolphins observed within water of different depth ranges and summarized these data with percentages by water depth bins. Because the water depth bins are small (5 m) and these dolphins remain in shallow water, the water depths were used as a proxy for dive depths. Ali et al. (2023) also provided an activity budget. Based on the description of each activity in Ali et al. (2023), it was assumed that the percentage of time that Irrawaddy dolphins spent in the surface bin included all time spent in milling and resting behaviors. Therefore, this was factored in the depth distribution given in Table 2-13.

Table 2-13. Percentage of time at depth for the Irrawaddy dolphin[1]

Depth Bin (m)	% of Time at Depth
0–5	65.0
5–10	29.0
10–15	5.4
15–200	0.6

[1] Based on data from Ali et al. (2023).

Although other research did not include usable depth distributions for Irrawaddy dolphins, some studies did provide additional information to categorize dive behavior. Mahmad et al. (2018) found that Irrawaddy dolphins dive most often to depths of 15–19.99 m and 20–30.4 m when foraging behind trawlers in Brunei Bay, Malaysia. Groups with calves are less likely to forage behind trawlers (Mahmud et al. 2018). Rodriguez-Vargas et al. (2019) studied Irrawaddy dolphins in waters around Penang Island, Malaysia, and found that dolphins mainly occurred in waters that were between 1.2 and 11.3 m deep. Jackson-Ricketts et al. (2020) found that the highest probability of dolphin presence in their study occurred at approximately 10.0 m with an optimal depth range of 7.50–13.05 m. These data generally align with the profile in Table 2-13.

2.2.1.2.10 *Orcinus orca*, Killer Whale

Killer whales have a cosmopolitan distribution but are most commonly observed in temperate, coastal waters (Ford 2002). Killer whales feed on a variety of prey, although most populations exhibit some degree of dietary specialization. In the northeastern Pacific and Antarctic, sympatric populations in each location are socially (and, in some cases, reproductively) isolated by foraging specializations for fish or marine mammal species (Ford et al. 1998; Pitman and Ensor 2003; Saulitis et al. 2000).

Although there is a separation of diving behaviors based on preferred prey of the killer whale, the killer whale density data required that killer whales not be differentiated in this manner. So, while there could be two separate representative depth distributions compiled for killer whales, based on whether they are fish-eating killer whales or mammal-eating killer whales, only the profile for fish-eating killer whales was used. Fish-eating killer whales have been studied more extensively than mammal-eating ecotypes, although there is still limited published information on diving behavior of either. Fish-eating killer whales will either chase individual prey at the surface, or collectively herd schooling fish towards the surface (Dietz et al. 2020; Domenici et al.

2000; Nøttestad et al. 2002a). Mammal-eating killer whales have different foraging strategies than fish-eating killer whales (Barrett-Lennard et al. 1996; Pitman and Ensor 2003). Mammal-eating killer whales often attempt to capture prey from below, where a prey's silhouette against brighter surface waters may improve detection. Miller et al. (2010) found deeper dives for mammal-eating killer whales occurred during the day. Because fish-eating killer whales spend longer percentages of time in surface waters, this profile is considered more conservative for use in the model.

To build a representative depth distribution for fish-eating killer whales, data from Figure 2 in Sivle et al. (2012), Figure 1e in Kvadsheim et al. (2012), and plots from post-sonar exposure and/or silent pass of the ship from Miller et al. (2011) were used. Since all three studies analyzed the potential effects of sonar on the dive behavior of killer whales, only dive profiles from periods of time when no sonar was active were used. Depth distributions were extracted from the presented dive profiles. Individual depth distributions for each animal were averaged to create the representative depth distribution in Table 2-14.

Table 2-14. Percentage of time at depth for fish-eating killer whales[1]

Depth Bin (m)	% of Time at Depth
0–20	81.5
20–40	8.6
40–60	4.5
60–80	2.4
80–100	2.1
100–120	0.5
120–140	0.3
140–150	0.1

[1] Based on data from Kvadsheim et al. (2012), Miller et al. (2011), and Sivle et al. (2012).

Although other studies did not include usable depth distributions for killer whales, they did provide additional information to categorize dive behavior. This representative depth distribution is consistent with Baird (1994) and Shapiro (2008), who reported that fish-eating resident killer whales spent the vast majority of their time in the top 20 m. Wright et al. (2017) similarly states that fish-eating killer whales spend little time below 30 m. Wright et al. (2017) examined the dive behavior for foraging versus non-foraging dives and attempted to align confirmed prey capture with a specific depth. Killer whales in this study were found to typically be after Coho salmon in depths deeper than 100 m; however, foraging dives comprised only 6.7 percent of dives recorded (by number). Non-foraging dives recorded were 64.7 percent, and none of these exceeded 21 m depth (Wright et al. 2017). This is consistent with the distribution in Table 2-14. Baird et al. (2005a) tagged a total of 34 Southern Resident killer whales and the average of all the tagged killer whale deepest dives was 141 m, which is consistent with the depth distribution in Table 2-14 (Baird et al. 2005a). Studies in different locations found a wide variety of maximum dive depths, likely based on depth of preferred prey (Baird et al. 2005a; Richard et al. 2020; Schorr et al. 2022; Towers et al. 2019). Schorr et al. (2022) found that offshore killer whales use the water column broadly and forage on the seafloor in certain locations. Towers et al. (2019) and Richard et al. (2020) were both studying depredation by whales, which occurs when whales remove fish caught on longlines. This practice may lead to deeper foraging dives by whales than normal, as compared to when whales naturally chase or herd fish (Towers et al. 2019).

2.2.1.2.11 *Peponocephala electra*, Melon-Headed Whale

Melon-headed whales occur in oceanic tropical and subtropical waters (Baird et al. 2021; Claridge et al. 2015; Joyce et al. 2017; Joyce et al. 2016; Perryman et al. 1994; West et al. 2018). Melon-headed whales feed on a variety of mesopelagic fish (e.g., myctophids) and cephalopod (Brownell Jr. et al. 2009; Gross et al. 2009; Jefferson and Barros 1997; West et al. 2018). Inferences can be made on the dive behavior of the melon-headed whale from the primary prey species, myctophids, which are vertical migrators that descend to depths of 700 to 3,000 m during the day and rise to 200 m or less at night (Clarke 1973). Cephalopods are also vertical migrators, descending to depths of 400 to 700 m during the day and rising to 100 to 150 m at night (Young 1978).

Melon-headed whales are assumed to only feed at night (Brownell Jr. et al. 2009; Claridge et al. 2015). Multiple tagging studies have found that these whales mainly dive below the surface only at night, foraging at depths of 50 to 525 m (Claridge and Durban 2008; Joyce et al. 2017; Joyce et al. 2016; West et al. 2018). Tagged whales from one study were found to frequently dive to depths of 300 to 350 m at night, while never diving deeper than 25 m during daylight hours (Joyce et al. 2017). This corresponds to data from Claridge et al. (2015), which recorded a median nighttime forage dive of 336 m and a maximum dive of roughly 500 m. In West et al. (2018), median dive depths were between 219 and 247 m. Noren and West (2020) found high levels of myoglobin in adult melon-headed whales. High myoglobin levels likely aid melon-headed whales in endurance swimming, rather than in prolonged diving, as they are acknowledged to not be deep or long-duration divers (Noren and West 2020).

Due to the lack of available data on the percentage of time at depth for the melon-headed whale, it will be represented by a surrogate species: the Risso's dolphin (Section 2.2.1.2.4). Both species are members of the same subfamily, Globicephalinae, feed on mesopelagic prey, and are similar in size. The closest relative to the melon-headed whale is actually the pilot whale; however, pilot whales are more than twice the size of melon-headed whales (LeDuc et al. 1999). The small size of melon-headed whales may indicate that they do not dive as deeply as their larger relatives, which is supported by the maximum dive depth data from Joyce et al. (2017; 2016), Claridge et al. (2015), and West et al. (2018), where the maximum depth ranged from 450 to 504 m. Therefore, the Risso's dolphin is a more suitable surrogate species for dive behavior than the pilot whale. The depth distribution for the melon-headed whale is given in Table 2-11.

2.2.1.2.12 *Pseudorca crassidens*, False Killer Whale

False killer whales inhabit tropical and temperate waters along and offshore of the continental slope (Baird et al. 2021; Odell and McClune 1999). Stomach content analyses have revealed that false killer whales feed on oceanic cephalopods (Alonso et al. 1999; Andrade et al. 2001), while observations indicate that they consume a variety of prey (including fish and other marine mammals) both at depth and at the surface (Acevedo-Gutiérrez et al. 1997; Perryman and Foster 1980; Stacey et al. 1994).

Little data have been collected on the dive behavior of the false killer whale. Cummings and Fish (1971) estimated that false killer whales would be capable of diving to depths up to 500 m. Based on measurements of their echolocation clicks, whales may detect large fish at up to distances of 200 m and cephalopods at about half that distance (Madsen et al. 2004a), which may suggest false killer whales are capable of diving to at least 200 m. Unpublished time-depth recorder data of a single whale showed that all dives to deeper than 100 m occurred during the day, with a maximum depth exceeding 234 m (Baird 2009). Dives during the nighttime remained within the top 100 m of the water column. Ligon and Baird (2001) reported that three instrumented whales showed a maximum diving depth of 53 m, with an average dive depth range of 8 to 12 m; however, the time of day that the dives occurred was not reported.

Due to the lack of available data on the diving behavior of the false killer whale, it will be represented by a surrogate species: the Risso's dolphin (Section 2.2.1.2.4). The closest relatives to the false killer whale for which diving behavior has been studied are three members of the subfamily Globicephalinae: the short- finned pilot whale, the long-finned pilot whale, and the Risso's dolphin (LeDuc et al. 1999). False killer whales are in between these species in size, but the limited data suggest that false killer whales do not dive as deep as pilot whales. Risso's dolphins and false killer whales also both feed on pelagic cephalopods (Clarke and Pascoe 1985). The depth distribution for the false killer whale is given in Table 2-11.

2.2.1.2.13 *Sousa chinensis*, Indo-Pacific Humpback Dolphin

Indo-Pacific humpback dolphins occur in shallow tropical to warm temperate coastal waters, often entering river mouths, estuaries, and mangroves (Jefferson et al. 2015). Although there are differences among species and populations, humpback dolphins are never very far from land nor in waters deeper than about 30 m (Jefferson et al. 2016; Parsons 2004). Depending on location, maximum water depths in which Indo-Pacific humpback dolphins are found range from 10 to 50 m (Parsons 2004). Indo-Pacific humpback dolphins have been recorded feeding across the water column on teleost fish and cephalopods (Alkhamis et al. 2024; Lin et al. 2021; Parra and Jedensjö 2014).

In multiple areas of the Indo-Pacific region, the range of the Indo-Pacific humpback dolphin overlaps with that of the Indo-Pacific bottlenose dolphin, with humpback dolphins tending to occupy shallower and more nearshore areas than bottlenose dolphins (Syme et al. 2023). To build a representative depth distribution for Indo-Pacific humpback dolphins, data were derived from the text in Haughey (2021), based on Indo-Pacific bottlenose dolphins. Survey data showed that Indo-Pacific bottlenose dolphins spent 24 percent of their time in a combination of milling and resting; therefore, at a minimum, 24 percent of their time was spent in the 0–5 m surface bin. However, all behaviors (i.e., foraging, socializing, and travelling) resulted in some time spent in this bin. The activity budget provided in Haughey (2021) was then factored into an approximate breakout assuming that at least 30 percent of each animal's time was spent at the surface, while the remaining bins, based on activity would be approximately 50 percent and 19 percent and 1 percent. These bins were then adjusted to incorporate an activity budget from Piwetz et al. (2021). The depth distribution for Indo-Pacific bottlenose dolphin is given in Table 2-15.

Table 2-15. Percentage of time at depth for the Indo-Pacific humpback dolphin[1]

Depth Bin (m)	% of Time at Depth
0–5	47.5
5–10	37.5
10–20	14.25
20–200	0.75

[1] Haughey (2021) and Piwetz et al. (2021).

Although other studies did not include usable depth distributions for Indo-Pacific humpback dolphins, studies did provide additional information to categorize dive behavior. Serres et al. (2024) recorded dolphins foraging in the South China Sea at an average depth of 7.5 m for an average of 27.5 min. Serres et al. (2024) also recorded Indo-Pacific humpback dolphins resting near the surface for dozens of seconds. Other studies have recorded Indo-Pacific humpback dolphins inhabiting waters that ranged from 0.97 to 24.8 m deep at locations along the coast of Taiwan and in the Beibu Gulf, China (Guan et al. 2015; Wang et al. 2007; Wu et al. 2017). The depths at which dolphins were recorded are typical depths in which Indo-Pacific humpback dolphins are found as shown in Table 2-15.

2.2.1.2.14 *Stenella attenuata*, Pantropical Spotted Dolphin

Pantropical spotted dolphins are found in warm temperate and tropical waters over the continental slope and offshore in deeper waters (Perrin and Hohn 1994). Pantropical spotted dolphins feed on both epipelagic and mesopelagic fish and squid (Wang et al. 2003). In general, pantropical spotted dolphins dive deeper at night, foraging on prey associated with vertical migrations of the deep scattering layer (Robertson and Chivers 1997; Scott and Chivers 2009; Silva et al. 2016).

To build a representative depth distribution for pantropical spotted dolphins, data from Figure 4 and Table 2 in Baird et al. (2001) and Figure 9 and Table 2 in Scott and Chivers (2009) were used. Although Baird et al. (2001) looked at pantropical spotted dolphin diving behavior around the Hawaiian Islands, Scott and Chivers (2009) recorded data on these dolphins in pelagic waters. Baird et al. (2001) reported pantropical spotted dolphins spend on average 88.5 percent of their time within 10 m of the surface during the day.

Baird et al. (2001) reported the daytime average percentage of time in 2-m intervals for the top 10 m. For the Baird et al. (2001) nighttime and Scott and Chivers (2009) data, the percentage of time determined for the top 10 m was uniformly distributed across these 2-m intervals. Daytime and nighttime averages were calculated for the Baird et al. (2001) data, and these were then averaged with the Scott and Chivers (2009) data. The resulting mean daytime and nighttime depth distribution data are presented in Table 18. Baird reported maximum daytime and nighttime dive depths at 122 m and 213 m, respectively (Baird et al. 2001); however, Scott and Chivers (2009) calculated that dives to more than 120 m accounted for less than 0.1 percent of all dives. They also noted that daytime dives were primarily shallow and above the thermocline (Scott and Chivers 2009). The depth distribution for pantropical spotted dolphins is given in Table 2-16.

Table 2-16. Percentage of time at depth for the pantropical spotted dolphin[1,2]

Depth Bin (m)	% of Time at Depth
0–2	20.4
2–4	10.7
4–6	8.6
6–8	9.0
8–10	9.5
10–20	21.3
20–30	8.8
30–40	3.8
40–50	2.5
50–60	1.9
60–70	1.1

Depth Bin (m)	% of Time at Depth
70–80	0.6
80–90	0.6
90–100	0.4
100–110	0.4
110–120	0.15
120–130	0.05
130–140	0.05
140–150	0.05
150–160	0.05
160–170	0.05

[1] Based on data from Baird et al. (2001) and Scott and Chivers (2009).

[2] This depth distribution is also representative of the following species: common dolphin, Pacific white-sided dolphin, northern right whale dolphin, striped dolphin, and spinner dolphin.

Although other studies did not include usable depth distributions for pantropical spotted dolphins, they did provide additional information to categorize dive behavior. Silva et al. (2016) provided additional information that categorized the daytime dive behaviors of five pantropical spotted dolphins in Hawaiian waters. This study found that dolphins spent 76.9 percent of time in the top 10 m and were mainly found in shallow waters during daytime hours (Silva et al. 2016). Baird et al. (2001), which was used to create the representative dive profile from both daytime and nighttime data, reported higher percentages of time (i.e., 88.5 percent) than Silva et al. (2016) within 10 m of the surface during the day.

2.2.1.2.15 *Stenella coeruleoalba*, Striped Dolphin

Striped dolphins prefer tropical and warm temperate waters and have an oceanic distribution, with most observations occurring beyond the continental shelf (Archer II 2002; Cañadas et al. 2002; Chavez-Rosales et al. 2019; Davis and Fargion 1996; Davis et al. 1998; Perrin et al. 1994). Striped dolphins primarily feed on small, pelagic, vertically migrating prey (Blanco et al. 1995). Stomach contents analyses suggest that foraging occurs mostly in the dusk and early evening hours (Ringelstein et al. 2006). Their distribution in the North Atlantic Ocean is associated with a mesopelagic prey community composed of fish and cephalopod species (Doksaeter et al. 2008).

Little data has been collected on the dive behavior of the striped dolphin. A single striped dolphin carrying a time-depth recorder dove to a mean depth of 22.6 m (standard deviation [SD] = 17.5) during the day and 126.7 m (SD = 120.9) at night, with a maximum dive depth of 705 m (Minamikawa et al. 2003).

Due to the lack of available data on the diving behavior of the striped dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.14). The observed pattern of shallow daytime diving and deeper nighttime diving reported in Minamikawa et al. (2003) is consistent with similar diving behavior seen in common dolphins (Section

2.2.1.2.1) and their surrogate species, the pantropical spotted dolphin (Section 2.2.1.2.14), which is also in the genus *Stenella*. Additionally, all three species occur in similar water depths (Davis et al. 1998). However, it is acknowledged that the striped dolphin may dive to deeper depths on average, due to the deep maximum dive depth recorded by Minamikawa et al. (2003). The depth distribution for striped dolphins is given in Table 2-16.

2.2.1.2.16 *Stenella longirostris*, Spinner Dolphin

Spinner dolphins typically reside in tropical pelagic waters, although they have a coastal distribution around the Hawaii and French Polynesia island chains (Benoit-Bird and Au 2003). The prey of spinner dolphins consists of vertically-migrating mesopelagic fish, cephalopods, and crustaceans, as well as pelagic organisms concentrated in near-surface waters with a shallow thermocline (Lammers 2004; Reilly 1990).

No data have been collected on the dive behavior of the spinner dolphin. Many of the vertically-migrating prey of the spinner dolphin spend daytime hours at depths from 700 to 3,000 m but ascend at night to depths between the surface and 200 m. Spinner dolphins in Hawaiian waters mostly forage in deep water at dusk and early evening but dive to shallow depths due to the vertical migration of their prey at night (Benoit-Bird and Au 2003; Lammers 2004). Letessier et al. (2022) found, through visual sighting and passive acoustic monitoring, that spinner dolphins in their study participated in a regular diurnal behavior where dolphins would enter a lagoon in the morning and leave in the afternoon for nighttime foraging offshore.

Due to the lack of available data on the diving behavior of the spinner dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.14). Pantropical spotted dolphins also forage mostly at night on vertically-migrating fish and cephalopod prey and their foraging dives are primarily limited to the upper 200 m of the water column (Baird et al. 2001). Gross et al. (2009) found no niche differentiation between the two species. The depth distribution for striped dolphins can be found in Table 2-16.

2.2.1.2.17 *Steno bredanensis*, Rough-Toothed Dolphin

Rough-toothed dolphins are commonly found in waters along the continental shelf in tropical and warmer temperate waters (Baird et al. 2021; Davis et al. 1998; Shaff and Baird 2021). Rough-toothed dolphins have been reported feeding on squid and fishes near the surface, which may indicate that they primarily make shallow dives (Lodi and Hetzel 1999; Pitman and Stinchcomb 2002).

To build a representative depth distribution for rough-toothed dolphins, data from Table 9 in Wells et al. (2008) were used. Wells et al. (2008) reported time-at-depth data from four rehabilitated and released adult rough-toothed dolphins in the Atlantic Ocean and presented the percentage of dives to greater than 2 m for each animal. Although these data underestimate surface time (since an animal had to dive below 2 m depth for the tag to save the data), they indicate that rough-toothed dolphins spend the majority of their time in the upper 25 m of the water column. Only two of the four dolphins (three dives total) reached the 200- to 300-m depth bin, and dives were generally shallowest during the daytime. The data from Wells et al. (2008)

were averaged across all four animals. The depth distribution for rough-toothed dolphins is given in Table 2-17.

Table 2-17. Percentage of time at depth for the rough-toothed dolphin[1]

Depth Bin (m)	% of Time at Depth
0–10	78.6
10–25	16.24
25–50	3.81
50–75	0.93
75–100	0.29
100–150	0.11
150–200	0.01
200–300	0.01

[1] Based on data from Wells et al. (2008).

Other than the Wells et al. (2008) study, little data have been collected on the dive behavior of the rough-toothed dolphin. An early study by Watkins et al. (1987) reported rough-toothed dolphins rubbing against a deployed hydrophone at a depth of 70 m. A 2021 study of nine individuals by Shaff and Baird (2021) found tagged rough-toothed dolphins to have grand mean maximum dive depths of 76.9 m and 399.5 m. All tagged dolphins dove to depths greater than 203 m (Shaff and Baird 2021). The dolphins in the study were found to spend between 83.6 percent and 93.7 percent of time at depths less than 30 m (Shaff and Baird 2021). The Shaff and Baird (2021) study generally aligns with the data from Wells and colleagues, showing 84 percent to 94 percent of time between 0 and 30 m. Wells et al. (2008) recorded 94 percent of time at this depth, with dives below 130 m occurring rarely. The deepest recorded dive by Shaff and Baird was slightly deeper than observed by Wells and colleagues, measuring at 399 m (Shaff and Baird 2021).

2.2.1.2.18 *Tursiops aduncus*, Indo-Pacific Bottlenose Dolphin

Indo-Pacific bottlenose dolphins occur in shallow tropical to warm temperate coastal waters of the Indo-Pacific, with their distribution extending into some enclosed bodies of water (Jefferson et al. 2015). Considered principally a coastal species, these dolphins occur predominantly over the continental shelf, in shallow coastal and inshore waters (Cribb et al. 2013; Jefferson et al. 2015). Occasional movements across deep, oceanic waters have been reported (Wang 2018). Indo-Pacific bottlenose dolphins have been reported feeding on teleost fish and cephalopods (Alkhamis et al. 2024).

In multiple areas of the Indo-Pacific region, the range of the Indo-Pacific bottlenose dolphin overlaps with that of the Indo-Pacific humpback dolphin, with humpback dolphins tending to occupy shallower and more nearshore areas than bottlenose dolphins (Syme et al. 2023). To build a representative depth distribution for Indo-Pacific bottlenose dolphins, an activity budget from the text in Haughey (2021) was used. Survey data showed that Indo-Pacific bottlenose dolphins spent 24 percent of their time in a combination of milling and resting; therefore, at a minimum, 24 percent of their time was spent in the 0–5 m surface bin. However, all behaviors (i.e., foraging, socializing, and travelling) resulted in some time spent in this bin. The activity budget provided in Haughey (2021) was then factored into an approximate breakout assuming that at least 30 percent of each animal's time was spent at the surface, while the remaining bins, based on activity would be approximately 50 percent and 19 percent and 1 percent. The depth distribution for Indo-Pacific bottlenose dolphin is given in Table 2-18.

Table 2-18. Percentage of time at depth for the Indo-Pacific bottlenose dolphin[1]

Depth Bin (m)	% of Time at Depth
0–5	46.8
5–15	38.0
15–25	14.44
25–300	0.76

[1] Based on data from Haughey (2021).

Other than in Haughey (2021), little data have been collected on the dive behavior of the Indo-Pacific bottlenose dolphin. Wang (2018) noted that Indo-Pacific bottlenose dolphin dive depths and durations are thought to be less than 200 m and from 5 to 10 min. Swimming speeds range from 0.8 to 2.2 knots, but bursts of higher speeds can reach 8.6 to 10 knots (Wang 2018). Corkeron and Martin (2004) recorded two tagged Indo-Pacific bottlenose dolphins spending two-thirds of their time in the top 5 m of the water column off eastern Australia.

2.2.1.2.19 *Tursiops truncatus*, Common Bottlenose Dolphin

Common bottlenose dolphins have a cosmopolitan distribution in the tropical and temperate waters of the world (Wells and Scott 2002). They reside in estuarine, coastal, and offshore continental shelf and slope waters. Populations vary in their migratory and foraging behavior (Wells and Scott 2002). Common bottlenose dolphins feed primarily on fish species, with squid and other invertebrates contributing to their diet as well (National Marine Fisheries Service 2015). Due to the range of habitats in which common bottlenose dolphins are found, prey species may be epipelagic, pelagic, mesopelagic, or benthic in origin, depending on the region and habitat (Mead and Potter 1990; Rossbach and Herzing 1997; Shane 1990; Wells and Scott 1999). The presence of deep-sea fish in the stomachs of some offshore animals suggests that they can dive to depths greater than 500 m (Reeves et al. 2002).

Little data have been collected on the dive behavior of common bottlenose dolphins. To build a representative depth distribution for common bottlenose dolphins, data from Table 4 in Klatsky (2004) were used. Dolphins 39999 and 40000 were tagged for 30 and 48 hours, respectively, whereas Dolphin 40001 was tracked for 45 days, providing 792 hours of dive data. So, while Klatsky (2004) presents the percentage of time at depth for three individuals, only the data from Tag 40001 were considered for the depth distribution to provide the most comprehensive view of common bottlenose dolphin diving behavior. Klatsky (2004) reported that the maximum recorded depth of a dolphin was 492 m; therefore, that was used as the maximum depth associated with this depth distribution. The depth distribution for common bottlenose dolphins is given in Table 2-19.

Table 2-19. Percentage of time at depth for the common bottlenose dolphin[1]

Depth Bin (m)	% of Time at Depth
0–6	64.6
6–10	3.9
10–26	5.7
26–50	2.5
50–76	2.0
76–100	1.7
100–150	3.6
150–200	2.5
200–250	2.1
250–300	2.2
300–350	1.9
350–400	1.7
400–450	1.6
400–492	4.0

[1] Based on data from Klatsky et al. (2004).

These data are consistent with animals foraging up to 500 m off Hawaii and spending the majority of their time between the surface and 50 m (Baird et al. 2021; Baird et al. 2014). A separate study by the same author, also off the coast of Hawaii, recorded maximum dive depths greater than reported in Table 2-19—up to 623.5 m (Baird et al. 2021). However, the median depth of foraging dives (for dives deeper than 50 m) was 311.5 m (Baird et al. 2021). Because depths were not reported for dives to less than 50 m, it is unclear whether or not these dive data are consistent with the data in Table 2-19.

2.2.1.3 Family Eschrichtiidae

2.2.1.3.1 *Eschrichtius robustus*, Gray Whale

Gray whales are distributed coastally throughout the Pacific Ocean, migrating annually between Arctic and subtropical waters (Jones and Swartz 2002; Swartz 1986). Gray whales forage within the water column with modified skimming techniques to capture neritic fish and will scrape along the benthos to acquire benthic fish, squid, annelids, crustaceans, and mollusks (Darling et al. 1998; Dunham and Duffus 2002; Jones and Swartz 2002; Nerini 1984). Gray whales have been reported foraging in water up to 120 m deep (Cacchione et al. 1987; Dunham and Duffus 2002; Würsig et al. 1986), although in many areas these whales forage in waters less than 20 m deep (Guerrero 1989; Ljungblad et al. 1987; Malcolm and Duffus 2000; Malcolm et al. 1995; Stewart et al. 2001; Woodward and Winn 2006).

To build a representative depth distribution for gray whales, data from Figure 3 in (Malcolm et al. 1995) were used. Malcolm et al. (1995) reported the percentage of time at depth for a single foraging whale carrying a tag for over 8 hours in waters off British Columbia in an area with a mean bottom depth of 18 m. The majority of dives (76 percent) were ventilation dives (to a mean depth of 2.3 m), while 13 percent were feeding dives (to a mean depth of 16.7 m). The whale appeared to spend little time at intermediate depths within the water column, spending most of its time either at the surface breathing or at the bottom feeding. Due to the large size of gray whales, the data from Malcolm et al. (1995) were summed into 4-m bins for the representative depth distribution. The depth distribution for gray whales is given in Table 2-20.

Table 2-20. Percentage of time at depth for the gray whale[1]

Depth Bin (m)	% of Time at Depth
0–4	39.0
4–8	8.5
8–12	7.0
12–16	16.0
16–20	28.0
20–22	1.5

[1] Based on data from Malcolm et al. (1995).

Although other studies did not include depth distributions for gray whales, they did provide additional information to categorize dive behavior. The representative depth distribution data compare to a later study with a larger sample size of whales, where 79 percent of dives by whales off Vancouver Island were to a mean depth of 2.2 m, and 15 percent of dives were to a mean depth of 12 to 19 m (Malcolm and Duffus 2000). Woodward and Winn (2006) and Woodward (2006) similarly reported that six whales feeding along the central British Columbia coast had a mean dive depth of 11 m (range 2.4–28.9 m). The percentage of time near the surface (19.5 percent from 0 to 2 m) is also consistent with other studies in the same region (14.2 percent and 17.5 percent) (Stelle et al. 2008) and in the Bering Sea (22 percent) (Würsig et al. 1986).

Furthermore, the dive depth is similar to the reported foraging depths in British Columbia and other regions (Guerrero 1989; Ljungblad et al. 1987; Malcolm and Duffus 2000; Malcolm et al. 1995; Stewart et al. 2001; Woodward and Winn 2006). Stewart et al. (2001) described the diving behavior post-release for a rehabilitated calf in southern California. All dives were less than 20 m deep, and 85 percent of dives were less than 10 m deep. An earlier release of a post-rehabilitated calf in the same area documented a much deeper maximum diving depth (170 m) and an average diving depth of approximately 50 m (Evans 1974), which is deeper than in the representative depth distribution.

2.2.1.4 Family Kogiidae

2.2.1.4.1 *Kogia breviceps, Pygmy Sperm Whale*

Pygmy sperm whales have a cosmopolitan distribution in all temperate and tropical waters (Bloodworth and Odell 2008). Mid- and deep-water cephalopods predominantly contribute to the diet of the pygmy sperm whale (Beatson 2007; Bloodworth and Odell 2008; Fernandez et al. 2009; McAlpine et al. 1997; Ross 1979; Santos et al. 2006).

Little data have been collected on the dive behavior of pygmy sperm whales. These whales are difficult to observe, due to long dive times and shallow blows, and their skittish nature makes tagging exceptionally difficult (Hildebrand et al. 2019). Sightings of pygmy sperm whales in the North Atlantic are most common in waters ranging from 400 to 1,000 m in depth (Clarke 2003; McCullough et al. 2021; Scott et al. 2001; Waring et al. 2006). Based on the analysis of the stomach contents of whales stranded in New Zealand, Beatson (2007) concluded that pygmy sperm whales feed at shallower depths within the water column than sperm whales, although some prey species are found at depths greater than 600 m. Plon (2004) found that prey species from the stomachs of stranded pygmy sperm whales in South Africa are found at depths below 300 m. More recent studies suggest that they may feed as deep as 600 to 1,000 m (Hildebrand et al. 2019; McCullough et al. 2021).

Due to the lack of available data on the diving behavior of the pygmy sperm whale, it will be represented by the surrogate species: the short-finned pilot whale (Section 2.2.1.2.3). The short-finned pilot whale is another primarily squid-eating species (Mintzer et al. 2008; Reeves et al. 2002) that forages deep in the water column (Jensen et al. 2011). The broad similarity in prey types and oceanic habitat suggests similarity in diving behavior to the short-finned pilot whale. The depth distribution for the pygmy sperm whale can be found in Table 2-10.

2.2.1.4.2 *Kogia sima*, Dwarf Sperm Whale

Dwarf sperm whales have a cosmopolitan distribution in all temperate and tropical waters (Willis and Baird 1998). Little data have been collected on the dive behavior of dwarf sperm whales, due in large part to the difficulties associated in tagging this species (Hildebrand et al. 2019). There is some indication that dwarf sperm whales have a more coastal distribution than pygmy sperm whales, and prey often include more continental shelf and slope species than those of the pygmy sperm whale (Ross 1979; Wang et al. 2002). The preferred prey species of dwarf sperm whales are found deep in the water column, with some species found below 400 m (Wang et al. 2002). Recent research suggests that the feeding depths for *K. sima* may be similar to *K. breviceps*, in that it frequents deeper shelf and slope waters from 600 to 1,000 m; thus, use of the same surrogate is appropriate (Hildebrand et al. 2019).

Due to the lack of available data on the diving behavior of the dwarf sperm whale, it will be represented by the surrogate species: the short-finned pilot whale (Section 2.2.1.2.3). The broad similarity in depth at which preferred prey can be found and their oceanic habitat suggests similarity in diving behavior to the short-finned pilot whale. In addition, the dwarf sperm whale's closest relative, the pygmy sperm whale, is also represented by the short-finned pilot whale. The depth distribution for the dwarf sperm whale can be found in Table 2-10.

2.2.1.5 Family Phocoenidae

2.2.1.5.1 *Phocoenoides dalli and Phocoenoides dalli truei*, Dall's Porpoise

Dall's porpoises can be found in the subarctic and cool temperate North Pacific Ocean, including the Bering Sea, Okhotsk Sea, and Sea of Japan (Jefferson 2002). Primary prey species include epipelagic and mesopelagic schooling fish and cephalopod species (Jefferson 1988; Ohizumi et al. 2000; Stroud et al. 1981; Walker 1996).

To build a representative depth distribution for the Dall's porpoise, data from Figures 3 and 4 in Baird and Hanson (1998) were used. Baird and Hanson (1998) tagged three Dall's porpoises with time-depth recorders in the waters between Washington State and British Columbia. Each animal had a median dive depth of less than 40 m, and maximum dive depths ranged from 197 to 278 m. Data from the tagged Dall's porpoises were averaged together to create the representative depth distribution below. The depth distribution for Dall porpoises is given in Table 2-21.

Table 2-21. Percentage of time at depth for the Dall's porpoise[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–1	5.3	50–60	4.8
1–2	15.7	60–70	4.7
2–3	8.8	70–80	3.8
3–4	3.2	80–90	2.3
4–5	3.8	90–100	2.0
5–6	1.7	100–110	1.1
6–7	1.0	110–120	0.7
7–8	1.3	120–130	0.4
8–9	1.3	130–140	0.5
9–10	1.8	140–150	0.4
10–11	1.3	150–160	0.3
11–20	11.7	160–170	0.3
20–30	8.3	170–180	0.3
30–40	6.8	180–190	0.3
40–50	6.2	190–200	0.1

[1] Based on data from Baird and Hanson (1998).

The representative depth distribution is consistent with stomach contents analyses, which suggest that Dall's porpoises feed high in the water column on vertically-migrating mesopelagic species, but they occasionally forage on deeper benthic prey (Jefferson 1988; Ohizumi et al. 1998). Recent modeling work suggests that, although these profiles are limited in scope, they are an accurate representation of the generally shallow coastal dive behavior for this species (Becker et al. 2014).

2.2.1.5.2 *Phocoena phocoena*, Harbor Porpoise

Harbor porpoises inhabit temperate and subarctic continental shelf waters in the northern hemisphere. Their diet consists primarily of fish, including both pelagic schooling and benthic species (Bjorge and Tolley 2002; Recchia and Read 1989). Cephalopods, crustaceans, euphausiids, and polychaetes also contribute to their overall diet (Recchia and Read 1989; Smith and Read 1992; Walker et al. 1998).

To build a representative depth distribution for harbor porpoises, data from Figure 3 in Otani et al. (1998); Figures 2 and 3 in Westgate et al. (1995); Figure 1 in Otani et al. (2000); Figures 2, 3, and 4 in Cooper et al. (1993); and Figure 7 in Westgate and Read (1998) were used. Cooper (1993) reported that porpoises in the Bay of Fundy were capable of diving to 150 m but spent most of their time in the top 50 m of the water column. Westgate et al. (1995) reported porpoises diving to a maximum of 226 m but also reported that average dive depth for individual porpoises ranged from 14 to 41 m and the depth range with the greatest proportion of dives was 2 to 10 m. Otani et al. (1998) found that harbor porpoises off the coast of Japan spent 74 percent to 86 percent of their time in the top 20 m of the water column, with an average dive depth of 12–19 m. The time at depth was visually inspected and averaged from all of the above figures to create the depth distribution for the harbor porpoise. This was done to include a total of 14 different harbor porpoises in the dive distribution. Although data from Cooper (1993), Otani et al. (1998), and Westgate et al. (1995) show the number or frequency of dives to specific depth bins, these data will be used as a proxy for percentage of time spent at depth. The depth distribution for harbor porpoises is given in Table 2-22.

Table 2-22. Percentage of time at depth for the harbor porpoise[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	39.0	110–120	0.4
10–20	17.8	120–130	0.4
20–30	12.7	130–140	0.3
30–40	10.1	140–150	0.2
40–50	6.9	150–160	0.2
50–60	4.6	160–170	0.1
60–70	2.5	170–180	0.1
70–80	1.5	180–190	0.1
80–90	1.4	190–200	0.1
90–100	1.0	200–210	0.1
100–110	0.4	210–226	0.1

[1] Based on data from Cooper (1993), Otani et al. (2000), Otani et al. (1998), Westgate and Read (1998), and Westgate et al. (Westgate et al. 1995).

Although other studies did not include depth distributions for harbor porpoises, they did provide additional information to categorize dive behavior. Nielsen et al. (2018) found that the median maximum dive depth of 17 tagged harbor porpoises over the continental shelf off Greenland was roughly 200 m. Offshore, this median maximum dive depth actually decreased 150 to 200 m (Nielsen et al. 2018). In a study by Linnenschmidt et al. (2013), three harbor porpoises were tagged. Two of the harbor porpoises showed consistent diving activity throughout the day, while one harbor porpoise showed a diel diving pattern with few dives during the day. Teilmann et al. (2013) found harbor porpoises spent more time between 0 and 2 m at night than during the day; this may be due to the movement of their prey throughout the water column (e.g., herring and sprat) (Cardinale et al. 2003). Van Beest et al. (2018) found that bathymetry and sea surface salinity were the most important environmental drivers of porpoise fine-scale movements. Salinity is likely an environmental indicator of potentially important feeding areas, based on the associated tracked movements (van Beest et al. 2018).

2.2.1.6 Family Physeteridae

2.2.1.6.1 *Physeter macrocephalus*, Sperm Whale

The sperm whale has a cosmopolitan distribution, preferring deeper waters seaward of the continental shelf edge (Whitehead 2002). Females and immature males tend to inhabit tropical and temperate waters below 40 degrees latitude, while maturing and adult males move to higher latitudes, occurring in polar waters as adults (Whitehead 2002). Sperm whales feed on cephalopod species, primarily squid, as well as mesopelagic and demersal fish and occasionally crustaceans (Fiscus et al. 1989; Flinn et al. 2002; Kawakami 1980; Martin and Clarke 1986).

There are published differences in the foraging dive behavior of whales in different regions, depending on ocean depth. In general, time spent at depth for the Pacific regions is consistent with foraging dives of 400 to 1,300 m (Amano and Yoshioka 2003; Aoki et al. 2012; Aoki et al. 2007). Overall, sperm whales typically spend 70 percent to 80 percent of their time between 20 and 400 m (Sivle et al. 2012; Teloni et al. 2008). At mid and low latitudes, females and immature animals undertake stereotypic dives lasting about 45 min and to depths between 400 and 1,200 m (Teloni et al. 2008; Watwood et al. 2006). Off Japan, females and immature sperm whales performed similarly stereotyped dive patterns to 1,400 m, lasting 30 to 50 min (Aoki et al. 2012). Radically different dive behavior has been observed at high latitudes, where mature males undertake dives lasting up to 60 min and to depths of nearly 1,900 m (Sivle et al. 2012; Teloni et al. 2008).

To build a representative depth distribution for sperm whales in the Pacific Ocean, data from Aoki et al. (2007) were used. Aoki et al. (2007) tagged four whales off the coast of Japan. The mean dive depth for nighttime was 515 m averaged over the two tag locations; the mean dive depth for the daytime was 749.5 m. Although this may suggest a diel diving pattern that follows the availability of prey, the pattern seems to depend largely on location (Aoki et al. 2012). The depth distribution for sperm whales in the Pacific Ocean is given in Table 2-23.

Table 2-23. Percentage of time at depth for the sperm whale in the Pacific Ocean[1]

Depth Bin (m)	% of Time at Depth
1–50	30.2
50–100	4.8
100–150	3.3
150–200	3.3
200–250	3.1
250–300	2.5
300–350	2.5
350–400	3.6
400–450	5.3
450–500	6.5
500–600	9.8
600–700	6.5
700–800	8.6
800–900	8.4
900–1,000	1.3
1,000–1,100	0.3

[1] Based on data from Aoki et al. (2012).

In the representative depth distribution, maximum dive depths are a few hundred meters shallower than for sperm whales recorded diving in the Gulf of California (1,500 m to greater than 1,600 m) (Irvine et al. 2017; Mate and Nieukirk 1992). In the Gulf of Alaska, whales were recorded diving to depths of 800 m, which was indicative of the depth of the seafloor (Mathias et al. 2012). Sperm whales off the coast of New Zealand spent the majority of their underwater (i.e., non-surface) dive time at depths of 300 to 600 m and dove to maximum depths of 943 m (Miller et al. 2013).

2.2.1.7 Family Ziphiidae

2.2.1.7.1 *Berardius bairdii*, Baird's Beaked Whale

Baird's beaked whales inhabit temperate waters of the North Pacific Ocean and adjoining seas, primarily in the deep waters offshore of the continental shelf (Balcomb 1989; Kasuya 1986). This species consumes benthic and epibenthic fish and cephalopods, and occasionally feeds on mesopelagic species as well (Balcomb 1989; Kasuya 1986; Walker et al. 2002).

Little data have been collected on the dive behavior of Baird's beaked whales. Stomach contents analysis suggests that whales are feeding at depths of 800 to 1,200 m off Japan, feeding on prey at or near the seafloor (Reeves et al. 2002; Walker et al. 2002). Minamikawa et al. (2007) reported that one animal carrying a time-depth recorder dove down to a maximum depth of 1,777 m, with dives lasting up to 64.4 min, which is similar to the maximum dive duration of 67 min observed by Kasuya (Kasuya 1986). The maximum dive depth reported by the first deployment of a multi-sensor tag on this species was given as roughly 1,400 m (Stimpert et al. 2014).

Due to the lack of data on the diving behavior of the Baird's beaked whale, it will be represented by a surrogate species: the goose-beaked whale (Section 2.2.1.7.5). The goose-beaked whale is also a member of the subfamily Ziphiidae, and the feeding habits and types of prey for the two species are similar. The diving pattern of Baird's beaked whales appears very similar to other beaked whales, in which a long-duration deep dive is followed by shorter-duration shallow dives (Minamikawa et al. 2007; Tyack et al. 2006). The depth distribution for the Baird's beaked whale can be found in Table 2-25.

2.2.1.7.2 *Indopacetus pacificus*, Longman's Beaked Whale

Longman's beaked whales inhabit generally warm, deep, pelagic waters of tropical and subtropical regions (McCullough et al. 2021). Little is known about the Longman's beaked whale's feeding behaviors. Similar to other beaked whales who dive deep to forage for food, their diet most likely consists primarily of cephalopods (Yamada 2002).

Little data have been collected on the dive behavior of Longman's beaked whales. The existence of Longman's beaked whales had previously only been known from the skeletal remains of stranded animals (Moore 1972; Pitman 2002a). However, some live sightings (Dalebout et al. 2003; Pitman et al. 1999) and acoustic recordings (McCullough et al. 2021) have been recognized as this species. Dive times have been found to last from 11 to 33 min, although one dive may have been over 45 min (Anderson et al. 2006; Gallo-Reynoso and Figueroa-Carranza 1995).

Due to the lack of available data on the diving behavior of the Longman's beaked whale, it will be represented by a surrogate species: the Blainville's beaked whale (Section 2.2.1.7.4). Though originally placed in the *Mesoplodon* genus, differences in features of the skull have led to the reclassification of this species into its own genus, *Indopacetus*; the previous classification in the same genus, with the current classification into the same family, is the primary reason for using the Blainville's beaked whale as the surrogate species. The depth distribution for the Longman's beaked whale can be found in Table 2-24.

2.2.1.7.3 *Mesoplodont* Beaked Whale Guild

Beaked whales are represented as guilds due to the difficulty of identifying beaked whales at sea to the individual species level and because this information was separated out in the density data used in the model. The beaked whale guild comprises Mesoplodon species that would be present in the SURTASS LFA Sonar Training and Testing Study Area: Hubb's beaked whale (*M. carlhubbsi*), Blainville's beaked whale, ginkgo-toothed beaked whale, Deraniyagala's beaked whale (*M. densirostris*), Stejneger's beaked whale (*M. stejnegeri*), and spade-toothed beaked whale (*M. traversii*). With the exception of cold, polar waters, *Mesoplodon* beaked whales are distributed in all of the world's oceans in deep (greater than 2,000 m) pelagic waters. The distribution of ginkgo-toothed beaked whales is thought to be restricted to the tropical and warm-temperate waters of the North Pacific; however, this assumption is based on the location of stranded individuals (MacLeod et al. 2006). In the North Pacific Ocean, Stejneger's beaked whales occur in temperate to subarctic waters (Pitman and Brownell Jr 2020). The Hubbs' beaked whale is endemic to North Pacific waters, potentially with separate eastern and western populations (MacLeod et al. 2006). Spade-toothed beaked whales are thought to have a restricted distributional range in the southern Pacific Ocean and the southeastern Indian Ocean, ranging from Australia and New Zealand to Chile (MacLeod et al. 2006). The lesser-known Deraniyagala's beaked whale ranges throughout the tropical waters of the equatorial Indo-Pacific (Dalebout et al. 2014).

The depth distribution for Blainville's beaked whales (Section 2.2.1.7.4) was used as the representative species for this group. Blainville's beaked whales spend a greater percentage of time in the upper 100 m of water than the goose-beaked whale, making the model a more conservative estimate of affected beaked whales. The depth distribution of Mesoplodont beaked whales in the Study Area can be found in Table 2-24.

2.2.1.7.4 *Mesoplodon densirostris*, Blainville's Beaked Whale

Blainville's beaked whales inhabit deep temperate and tropical waters of the world's oceans (Pitman 2002b). Little is known about its prey species, but the diet of Blainville's beaked whales includes mesopelagic cephalopods, fish, and crustaceans (Herman et al. 1994; Hickmott 2005; MacLeod et al. 2003a; Mead 1989).

To build a representative depth distribution for Blainville's beaked whales, data were acquired from Figures 3a and 3b from Arranz et al. (2011), Figure 6 from Baird et al. (2005b), Figures 3a and 3b from Baird et al. (2006), Figure 1 from Barlow et al. (2013), Digital Acoustic Recording Tag (DTAG) data from Johnson and Aguilar de Soto (2008a, 2008b), DTAG data from Tyack (2010), and Figure 1b from Tyack et al. (2006). Arranz et al. (2011) tagged nine whales to collect acoustic and movement data in order to study buzz and click behaviors during dives; Figures 3a and 3b from that study show the dive profile of a male Blainville's beaked whale over a period of 17 hours. Baird et al. (2005b) tagged four Blainville's beaked whales and presented cumulative percentage of time spent at depth for two individuals: an adult female with a young calf, the daytime data for a large sub-adult or adult female, and the nighttime data for the same sub-adult or adult female. Different data from that same female whale were used to create another set of dive profiles after a 22.6-hour deployment, as published in Baird et al. (2006). Barlow et al. (2013) used DTAGs to collect acoustic information for beaked whales in an attempt to estimate density and abundance; Figure 1 in that study is a typical dive profile for a tagged whale captured over a 15-hour period. Raw DTAG data for two animals in the Canary Islands, provided by Johnson and Aguilar de Soto (2008a, 2008b), were binned as well as raw DTAG data from one animal in the Bahamas by Tyack (2010). Tyack et al. (2006) used DTAGs to create a representative dive profile for the Blainville's beaked whale in an attempt to study how depth impacts foraging tactics. Data from each source were arranged into 100-m bins, and those bins were averaged together to create a representative depth distribution. The depth distribution for Blainville's beaked whales is given in Table 2-24.

Table 2-24. Percentage of time at depth for the Blainville's beaked whale[1,2]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
1–100	54.3	800–900	4.7
100–200	10.2	900–1,000	3.0
200–300	3.8	1,000–1,100	2.2
300–400	3.2	1,100–1,200	1.8
400–500	3.7	1,200–1,300	1.1
500–600	3.4	1,300–1,400	0.55
600–700	3.8	1,400–1,500	0.05
700–800	4.2		

[1] Based on data from Arranz et al. (2011), Baird et al. (2005b), Baird et al. (2006), Barlow et al. (2013), Johnson and Aguilar de Soto (2008b; 2008), Tyack et al. (2006), and Tyack (2010).

[2] This depth distribution is also representative of Longman's beaked whale and the Mesoplodont beaked whales guild.

Although the maximum forage dive depth off the Bahamas was found to be 1,900 m (Claridge et al. 2015; Joyce et al. 2017), Joyce et al. (2020; 2016) found maximum dive depths of Blainville's beaked whales to reach 1,400 to 1,500 m, which is consistent with the data presented in Table 2-24. The percentage of time at foraging depths (roughly greater than or equal to 650 m) were reported to be between 20 percent and 30 percent (Claridge et al. 2015; Joyce et al. 2017), and these percentages correspond to the percentage of time at these depths reported above.

2.2.1.7.5 *Ziphius cavirostris*, Goose-Beaked Whale

Goose-beaked whales, formally known as Cuvier's beaked whales, inhabit slope waters with steep gradients around the world's oceans, with the exception of the high polar seas (Heyning 1989). Stomach contents analyses indicate that prey species include mesopelagic and benthic cephalopods, fish, and crustaceans (Heyning 1989; Hickmott 2005; Santos et al. 2001). However, it appears that goose-beaked whales eat mostly squid, and the majority of their prey are open-ocean species that occur well below the surface, including on or near the seafloor in deep water (Reeves et al. 2002).

To build a representative depth distribution for the goose-beaked whale, data from the following sources were used: Figure 1 from Aguilar de Soto et al. (2006), Figure 5 from Baird et al. (2005b), Figure 3c from Baird et al. (2006), Figure 2a from Baird et al. (2008), Figure 1 from Barlow et al. (2013), DTAG data from Johnson and Sturlese (2008), Figure 1a from Kvadsheim et al. (2012), and Figures 2a and 3a from Schorr et al. (2014). Aguilar de Soto et al. (2006) presented a time-depth profile of a goose-beaked whale off Italy over a 15.6-hour period. Baird et al. (2005b) presented the cumulative percentage of time spent at depth for an adult female during the day and at night. Similarly, Baird et al. (2008) looked at diel variation in goose-beaked whale diving behavior, presenting the cumulative percentage of time spent at depth for two tagged whales during both the day and night. Barlow et al. (2013) used DTAGs to collect acoustic information for beaked whales in an attempt to estimate density and abundance; Figure 1 in Barlow et al. (2013) is a typical dive profile for a tagged whale captured over a 15-hour period. Raw DTAG data collected on multiple occasions for an animal in Liguria, Italy, provided by Johnson and Sturlese (2008), were binned. Kvadsheim et al. (2012) presented changes in dive behavior in response to sonar, but, as this report portrays normal goose-beaked whale behavior, the portion of the dive profile provided by Kvadsheim et al. (2012) in which sonar was used has been omitted from the typical depth distribution calculated. Schorr et al. (2014) provided multi-day tag data for goose-beaked whales, allowing for observation of diel patterns in dive behavior. The depth distributions from these studies were averaged together to create the representative depth distribution provided in Table 2-25.

Table 2-25. Percentage of time at depth for the goose-beaked whale[1,2]

Depth Bin (m)	% of Time at Depth
0–100	32.3
100–200	10.3
200–300	11.7
300–400	5.5
400–500	4.1
500–600	3.9
600–700	5.1
700–800	4.1
800–900	3.4
900–1,000	4.8
1,000–1,100	4.3
1,100–1,200	3.3
1,200–1,300	2.2
1,300–1,400	1.4
1,400–1,500	1.1
1,500–1,600	0.3
1,600–1,700	0.9
1,700–1,800	0.5
1,800–1,900	0.8

[1] Based on data from Aguilar de Soto et al.(Aguilar de Soto et al. 2006), Baird et al. (2005b), Baird et al. (2006), Baird et al. (2008), Barlow et al. (2013), Johnson and Sturlese (2008), Kvadsheim et al. (2012), and Schorr et al. (2014).

[2] This depth distribution is also representative of Baird's beaked whale.

Although other studies did not include depth distributions for goose-beaked whales, they did provide additional information to categorize dive behavior. Shearer et al. (2019) tagged 11 animals off Cape Hatteras and found that most surface intervals were very short in duration, but all animals occasionally performed extended surface intervals. Neither Quick et al. (2020) nor Shearer et al. (2019) found a correlation between deep dives and surface intervals. Dives were bimodal with shallow dives occurring to 50 to 800 m and deep dives occurring to upwards of 800 m (Shearer et al. 2019). This representative depth distribution is consistent with foraging dives from 689 to 1,888 m in the Mediterranean Sea (Tyack et al. 2006), to 1,450 m off Hawaii (Baird et al. 2006), and to 1,900 m off the Bahamas (Claridge et al. 2015; Joyce et al. 2017; Joyce et al. 2016). Shearer et al. (2019) stated that the maximum dive depth is location- and prey-specific because goose-beaked whales are thought to feed on the seafloor rather than on a vertically-migrating layer. Barlow et al. (2020) found that near-bottom habitat is likely important for foraging, while Barlow et al. (2018) found that individuals in their study rarely foraged at or near the seafloor. Mean foraging depth is typically shallower than seafloor depth off California (Barlow et al. 2018; Barlow et al. 2020) but closer to the bottom off Cape Hatteras (Shearer et al. 2019). Based on the representative depth distribution in Table 2-25, goose-beaked whales spent 31.9 percent of their time between 0 and 100 m, 36.1 percent of time deeper than 500 m, and 23 percent of time deeper than 800 m. These values remain consistent with the data reported by Baird et al. (2008), in which goose-beaked whales spend 12.4 percent to 51.1 percent of their time at depths less than 50 m, and from 33.9 percent to 52.1 percent of their time at depths greater than 500 m. Barlow et al. (2020) found that goose-beaked whales spent almost twice as much time at near-surface depths at night versus during the day. Table 2-25 is also consistent with Joyce et al. (2017), which indicates 22.6 percent of their time is spent at depths greater than 800 m.

2.2.2 Carnivores

2.2.2.1 Family Mustelidae

2.2.2.1.1 *Enhydra lutris kenyoni*, Northern Sea Otter

The sea otter is a species that ranges around the North Pacific Ocean rim, from Baja California, Mexico, to the east coast of the Russian Kamchatka peninsula and the Kuril Islands toward Japan. Northern sea otters range from Washington to the Aleutian Islands, and across the Pacific to Hokkaido, Japan. Sea otters inhabit nearshore waters. Typically, due to water depths, foraging would occur closer to shore and resting may occur nearshore or further offshore (Lafferty and Tinker 2014; Laidre et al. 2009). Sea otter prey includes benthic invertebrates (abalone, sea urchins, mussels, clams, snails, crabs, and worms) and occasionally bottom fish (Kenyon 1981; Laidre and Jameson 2006; Riedman and Estes 1990).

Early studies of sea otter dive behavior assumed average dives to be within 10 to 30 m of the surface (Kenyon 1981), but one record reported recovery of a sea otter carcass from a crab pot set at 97 m (Newby 1975), and assumed the otter dove to that depth but perished after getting stuck in the crab pot. Thometz et al. (2016) examined the foraging dive behavior of southern sea otters off the coast of California and found that the deepest foraging dives were performed by males (the maximum depth was 88 m), while the maximum dive by a female was 69 m. Bodkin et al. (2004) examined dive distributions of 14 foraging northern sea otters in Port Althorp, southeast Alaska, from May through July. This study also found that dive behavior was related to sex and size, with females averaging a maximum dive depth of 49 m compared to 82 m for larger males (Bodkin et al. 2004). Wolt (2014) also examined the dive behavior of northern sea otters in Alaska but focused primarily on those with dependent pups. There are differences in distribution with age/sex classes, with juvenile males tending to rest and forage farther offshore than juvenile and adult females. Juvenile males also forage in deeper water than either female class (Ralls et al. 1995).

Thometz et al. (2016) found that the mean foraging dive depth for all otters was 8.3 m and the range of mean dives was 2.3 to 28.6 m. Bodkin et al. (2004) calculated that sea otters in their southeast Alaska study completed a mean of 174 foraging dives per day and that these dives averaged a depth of 18.9 m (SD = 4.6 m) (Bodkin et al. 2004). Foraging dives had a mean depth of 2.7 m (SD = 0.2 m) when compared to traveling dives by the same animals (Bodkin et al. 2004). An observational study of sea otters off northern Washington (Laidre and Jameson 2006) reported an average foraging dive time of 0.9 min (54 sec), consistent with both Bodkin et al. (2004) and Thometz et al. (2016). Finally, Wolt et al. (2012) looked at sea otter dive behavior in Simpson Bay, Alaska, where dives mirrored the bathymetry of the bay, which was roughly 30 m deep. Mean dive duration, depending on bathymetry, ranged from 62 to 114 sec for individual foraging dives (Bodkin et al. 2004; Thometz et al. 2016; Wolt et al. 2012).

Although dive data are available for foraging sea otters in southeast Alaska and coastal California, these foraging dives have been found to mirror the bathymetry of the local area. According to all existing dive data, sea otters may be found in up to 100 m of water (Bodkin et al. 2004; Thometz et al. 2016), depending on the bathymetry in the areas where the dive data were logged. Although most sea otters would forage in waters less than 40 m deep (Bodkin et al. 2004; Thometz et al. 2016; Wolt et al. 2012), it is assumed any sea otter found in more than 40 m of water would be diving to or near the bottom in order to forage, unless they are traveling, grooming, or participating in social interactions.

Although several studies have created activity budgets for sea otters (Bodkin et al. 2007; Esslinger et al. 2014; Wolt 2014; Yeates et al. 2007), the data from Laidre et al. (2006) is the most robust, utilizing the behavior of 25 sea otters. According to Laidre et al. (2006), within a 24-hour time budget where all age and sex classes of sea otters were combined, sea otters spent roughly 45 percent of their time resting, 41 percent of their time foraging, and 14 percent in "other" behavior. Laidre et al. (2006) classified "other" behavior (similar to (Gelatt et al. 2002)) as grooming, swimming, or any active non-feeding behavior. As discussed above, Bodkin et al. (2004) described this type of behavior as "traveling dives" and measured these dives as averaging around 2.7 m.

Sea otters are expected to forage at or near the seafloor; therefore, their dive depth is dictated by the bathymetry of the location (Wolt et al. 2012) in their typical coastal habitats. To build a representative depth distribution for the northern sea otter, the activity budget in Laidre et al. (2006) was used and adjusted for time spent underwater. The 0- to 5-m bin includes time spent underwater while traveling, participating in "other" behavior, and foraging between 0 and 5 m. The total percentage of time spent in the 0- to 5-m depth bin was calculated to be 29.2 percent of underwater time. The remaining 70.8 percent of underwater time would be expected to be at depths between 6 and 100 m (accounting for depths greater than the deepest recorded otter dive), and dependent on the water depth of the foraging area. The depth distribution of southern sea otters is given in Table 2-26.

Table 2-26. Percentage of time at depth for the sea otter[1]

Depth Bin (m)	% of Time in Other (Traveling) Behavior at Depth	% of Time Foraging at Depth	% of Time at Depth
0-5	25.5	3.7	29.2
6-100	0	70.8	70.8

[1] Based on data from Laidre et al. (2006).

2.2.2.2 Family Otariidae

2.2.2.2.1 *Callorhinus ursinus*, Northern Fur Seal

Northern fur seals occupy the pelagic waters of the North Pacific Ocean, Bering Sea, and Sea of Japan, ranging coastally as far south as Baja California, Mexico, and Japan, and with an at-sea southern limit around 35 degrees north (Gelatt and Lowry 2008). Northern fur seals are known to feed in the deep waters along the continental shelf break, as well as the shallower waters of the shelf itself (Gentry 2002; Ponganis et al. 1992). The diet of northern fur seals varies regionally and seasonally but is composed principally of finfish (e.g., Pacific herring, sand lance, capelin, myctophids) and squid; they will occasionally feed upon other prey such as birds and crustaceans (Ream et al. 2005; Riedman 1990).

To build a representative depth distribution for the northern fur seal, data from Table 1 in Kooyman et al. (1976) were used. The dive behavior and physiology from Table 1 in (Kooyman et al. 1976) show the number of dives recorded to specific depth bins. Thus, these data from Kooyman et al. (1976) will be used as a proxy for the percentage of time spent at depth. Kooyman et al. (1976) found that shallow dives (0–20 m) lasted less than 1 minute in duration. Deeper dives, from 20 to 140 m, lasted from 2 to 5 min. The maximum dive depth in this study was 190 m. The average interval between dives was 17 min. The depth distribution for northern fur seals is given in Table 2-27.

Table 2-27. Percentage of time at depth for the northern fur seal[1]

Depth Bin (m)	% of Time at Depth
0–20	48.36
20–50	42.32
50–80	5.94
80–110	0.96
110–140	1.99
140–170	0.39
170–200	0.04

[1] Based on data from Kooyman et al. (1976).

Although other studies did not include depth distributions for northern fur seals, they did provide additional information to categorize dive behavior. Because northern fur seals spend most of their lives at sea (87 percent to 90 percent of the year), only coming ashore to breed for 35 to 45 days from June to August, most of the tagging studies examine the dive behavior of females on excursions from breeding colonies in the Bering Sea (Baker 2007; Baker and Donohue 2000; Goebel et al. 1991; Jeanniard-du-Dot et al. 2017; Kooyman et al. 1976; Kuhn et al. 2009; Ream et al. 2005). In general, adult females on foraging excursions generally follow one of three dive profiles— shallow, deep, or mixed depth. Shallow-diving seals show a crepuscular pattern with dive depths varying according to movement of the deep scattering layer. Deep-diving seals show no temporal pattern, apparently ignoring the diel movements of vertically migrating prey, and have no consistent change in depth within bouts. Mixed-depth divers alternate between dive profiles, perhaps shifting what they are consuming (Gentry 2002). Female northern fur seals dive mostly at night (68 percent) (Gentry 2002). Individuals may be consistent in their diving behavior, presumably choosing prey sources at different depths, as evidenced by unique fatty acid profiles specific to a differentiated prey type (deep versus vertically migrating species, for example); however, other evidence points towards a seasonal shift in dive behavior (Gentry 2002; Gentry et al. 1986; Hobson and Sease 1998; Hobson et al. 1997). Radio-tracking studies suggest that deep-diving patterns are used while foraging on the continental shelf, while shallow-diving patterns occur over deeper waters off the shelf break or in the Aleutian Basin (Gentry et al. 1986; Goebel et al. 1991). Female northern fur seals have been recorded diving to a maximum depth of 256 m (Ponganis et al. 1992), although they most frequently dive between 50 and 60 m (Gentry et al. 1986). Female pups have shallower dives with a grand mean dive depth of 7.8 m (Lee et al. 2014). The activity budgets for adult females on foraging trips range from 9 percent to 17 percent of time spent resting, 26 percent to 29 percent of time spent diving, and 29 percent to 57 percent of time spent at the surface (Gentry et al. 1986; Jeanniard-du-Dot et al. 2017).

Male northern fur seal diving behavior has also been examined (Sterling and Ream 2004), revealing that (like parturient females), juvenile males exhibit shallow versus deep dive patterns based on foraging location (deep dives in water less than 200 m deep, shallow nighttime dives in waters up to 3,000 m deep). In a study of 19 juvenile male northern fur seals on foraging excursions during the breeding season in the Bering Sea, the maximum recorded dive depth was 175 m, with a mean dive depth of 17.5 m (SD = 1.5 m) (Sterling and Ream 2004). A different study found male juveniles to have a grand mean dive depth of 6.8 m in the Bering Sea (Lee et al. 2014).

2.2.2.2.2 *Eumetopias jubatus*, Steller Sea Lion

Steller sea lions inhabit the Pacific Ocean north of approximately 30 degrees north latitude (Loughlin 2002; Schusterman 1981). They feed on an assortment of shallow water fish, cephalopods, bivalves, and crustaceans (Schusterman 1981; Tollit et al. 2004). One study found that Steller sea lions feed on mackerel resting on the seafloor at night (Olivier et al. 2022).

To build a representative depth distribution for the Steller sea lion, data from Figure 2 and the text of Rehberg et al. (2009) were used. Rehberg et al. (2009) reported on the summer diving behavior of five adult sea lions belonging to the Eastern Alaska stock. They also summarized similar data on four Western Alaska stock females from Merrick (1995) and Merrick and Loughlin (1997). A dive was counted as any movement of the animal below 4 m depth. Due to the lack of data on time spent at depth, the data will be used as a proxy for depth distribution data. Skinner et al. (2012) and Rehberg et al. (2009) reported that, on average, females spent 15.1 percent and 22.1 percent of their time at sea submerged, respectively. Therefore, the distribution from Rehberg et al. (2009) will be adjusted to represent 22.1 percent of an animal's time, with 77.9 percent of time spent between depths of 0 to 4 m. The maximum dive depth reported in this study was 236 m. The resulting depth distribution is given in Table 2-28.

Table 2-28. Percentage of time at depth for the Steller sea lion[1]

Depth Bin (m)	% of Time at Depth
0–4	77.9
4–10	8.8
10–20	6.6
20–50	4.3
50–100	1.9
100–236	0.5

[1] Based on data from Rehberg et al. (2009) and Skinner et al. (2012).

Although other studies did not include usable depth distributions for Steller sea lions, they did provide additional information to categorize dive behavior. Olivier et al. (2022) found that 33 percent of foraging time was spent diving, with the rest of the time spent swimming near the surface. The depth distribution in Table 2-28 is consistent with research suggesting most dives are within the top 50 m (Fadely et al. 2005; Loughlin et al. 1998; Loughlin et al. 2003; Merrick and Loughlin 1997; Merrick et al. 1994; Olivier et al. 2022; Skinner et al. 2012). The maximum dive depth in Table 2-28 is shallower than in some studies (Loughlin et al. 2003; Olivier et al. 2022). However, there is evidence that adult females dive deeper during the winter than the summer (Merrick and Loughlin 1997; Merrick et al. 1994), although in both seasons the majority of dives are shallow (<50 m). The depths to which Steller sea lions dive aligns with the presence of prey. Though prey abundance is seasonally and geographically variable, the general assertion that Steller sea lions spend the majority of their time in the top 50 m of the water column is consistent (Sigler et al. 2009). Many studies use trained Steller sea lions to examine dive behavior (Fahlman et al. 2008; Hindle et al. 2010; Rosen et al. 2017; Volpov et al. 2016; Young et al. 2011) or use Steller sea lions that were in or recently released from captivity (Goundie et al. 2015; Thomton et al. 2008).

2.2.2.3 Family Phocidae

2.2.2.3.1 *Erignathus barbatus*, Bearded Seal

Bearded seals are limited to circumpolar Arctic and sub-Arctic waters that are relatively shallow (primarily less than about 490 m deep) and seasonally ice-covered because they are closely associated with sea ice. Bearded seals follow the advancement and retreat of the polar ice cap during seasonal migrations (Antonelis et al. 1994). To remain associated with their preferred ice habitat, bearded seals generally move north in late spring and summer as the ice melts and retreats and then south in the fall as sea ice forms. In U.S. waters, they are found off the coast of Alaska over the continental shelf in the Bering, Chukchi, and Beaufort Seas. Bearded seals are often found farther offshore than the sympatric ringed seal (Bengston et al. 2005). They are generalist feeders, consuming both pelagic and demersal fish, as well as epifaunal and infaunal invertebrates. Their main prey includes fish such as polar cod and capelin, crabs, shrimp, and mollusks (Antonelis et al. 1994; Hjelset et al. 1999; Lowry et al. 1980). Bearded seals primarily feed on or near the seafloor on invertebrates (e.g., shrimps, crabs, clams, and whelks) and some fish (e.g., cod and sculpin). Bearded seals are considered shallow divers, with most dives to less than 100 m (Kingsley et al. 1985). They do not like deep water and prefer to forage in waters less than 200 m deep where they can reach the ocean floor.

To build a representative depth distribution for bearded seals, data from Figure 4 in Gjertz et al. (2000b) were used. Gjertz et al. (2000b) reported diving behavior of adult females and their pups in shallow, coastal regions around Svalbard, Norway. This study provided an estimate of the percentage of dives to varying depths, which will be used as a proxy for the percentage of time at depth. The tags did not record data until deeper than 2 m, so an activity budget from Krafft et al. (2000) was used for a surface bin amount. Figure 1 in Krafft et al. (2000) showed that female seals in this study spent 48.37 percent of their time at the surface. Therefore, the average time spent at the surface from Krafft et al. (2000) was combined with the dive distribution data from Gjertz et al. (2000b) to generate an estimate of the depth distribution for the bearded seal. The depth distribution for bearded seals is given in Table 2-29.

Table 2-29. Percentage of time at depth for the bearded seal[1]

Depth Bin (m)	% of Time at Depth
0–2	48.37
2–10	19.43
10–20	5.24
20–30	1.86
30–40	3.39
40–50	5.21
50–60	6.35
60–70	5.0
70–80	1.98
80–90	1.35
90–100	0.58
100–150	1.17
150–200	0.07

[1] Based on data from Gjertz et al. (2000b) and Krafft et al. (2000).

Although other studies did not include usable depth distributions for bearded seals, they did provide additional information to categorize dive behavior. Watanabe et al. (2009) looked at the diving and swimming style of pups that were still nursing. The pups in this study spent roughly half of their time hauled out of the water. Olnes et al. (2020) provides a description of juvenile bearded seal movement, diving, and haul-out behaviors in the Pacific Arctic, obtained from 24 seals tagged with satellite-linked data recorders along Alaska's coast from 2014 to 2018. Olnes et al. (2020) found that seals spent half their time near the seafloor. Hauling out occurred less in the winter and increased during spring and summer, coinciding with the annual molting period. When ice was at its minimum extent, seven seals frequently hauled out on land. Hamilton et al. (2018) tagged five adult bearded seals with GPS-Argos-CTD-SRDLs in Svalbard, Norway, from 2011 through 2012 to document their diving, activity, and movement patterns. The seals spent little time hauled out (≤ 5 percent), while diving occupied 74 percent of their time. Dives were generally shallow (mean: 24 ± 7 m, maximum: 391 m) and of short duration (mean:

6.6 ± 1.5 min, maximum: 24 min) with deeper, longer dives in winter/spring compared to summer.

2.2.2.3.2 *Histriophoca fasciata*, Ribbon Seal

The ribbon seal inhabits the northernmost Pacific Ocean and Arctic Ocean, including the Chukchi Sea, with predominant occurrences in the Bering Sea and Sea of Okhotsk (Fedoseev 2000; Jefferson et al. 2015). Ribbon seals are associated with the southern edge of the pack ice from winter through early summer, where they pup and molt on the ice (Fedoseev 2000). During the summer months, seals tend to be more pelagic, encompassing a broader distributional range less associated with the sea ice (Jefferson et al. 2015). The year-round food habits of ribbon seals are not well known, in part because almost all information about ribbon seal diet is from March through June. From these samples, it is thought that ribbon seals prey on a variety of fishes, as well as cephalopods (Boveng et al. 2013). Some studies of respiratory physiology and blood parameters suggest ribbon seals have adapted to a pelagic environment and deep diving (Lowry and Boveng 2009).

In order to build a representative depth distribution for ribbon seals, data from tags deployed on ribbon seals by the National Oceanic and Atmospheric Administration were used. The resulting depth distribution profile includes data from 55 deployments on ribbon seals between 2005 and 2010. All tags were deployed on ribbon seals in the central Bering Sea or off the coast of Kamchatka, Russia. The data are unpublished and were compiled by Josh London (2020) and reported to the Naval Undersea Warfare Center (NUWC) Division Newport, Rhode Island. The depth distribution for ribbon seals is given in Table 2-30.

Table 2-30. Percentage of time at depth for the ribbon seal[1]

Depth Bin (m)	% of Time at Depth
0–10	8.0
10-30	14.0
30–50	8.0
50–70	12.0
70–100	35.0
100–150	16.0
150–200	3.0
200–600	4.0

[1] Based on data from personal communication with Josh London (2020) and tags deployed by Boveng et al. (2013).

Although other studies did not include usable depth distributions for ribbon seals, they did provide additional information to categorize dive behavior. Ribbon seals are presumed to be the deepest divers among Arctic seals (i.e., bearded, ringed, and spotted) (Boveng et al. 2013; Goertz et al. 2019). Boveng et al. (2013) discussed the general seasonality of dive behavior by ribbon seals. In early summer, when some ribbon seals have completed their molt and others are still molting, tagged seals' dives were spread throughout the water column to depths less than 500 m, with the mode at 71–100 m. From July to October, when ribbon seals are not on the ice for reproductive and molting requirements, the dives were more evenly spread over the top 500 m, with a few dives exceeding 600 m. In November, when ribbon seals return to the sea ice, dives were nearly all to 100 m or shallower, consistent with sea ice that is present only on the shelf region. As sea ice advanced south from December to March, the dive depths increased (Boveng et al. 2013). This seasonal pattern suggests that ribbon seals prefer to forage in deeper water when not constrained by available ice being too far from the continental shelf slope (Boveng et al. 2013). London et al. (2014) reported that seals often dove to water depths deeper than 200 m, with some dives even exceeding 600 m. Deguchi et al. (2004) suggested that ribbon seals likely dive to depths of at least 400 m, based on prey items in seals stomachs. Results from other studies are mostly consistent with the representative dive profile.

2.2.2.3.3 *Monachus schauinslandi*, Hawaiian Monk Seal

The range of the Hawaiian monk seal is limited to the central Pacific Ocean, with breeding colonies principally in the northwestern Hawaiian Islands (Gilmartin and Forcada 2002; Johanos and Baker 2002). Hawaiian monk seals primarily consume benthic prey; stomach contents and scat analyses indicate that prey constitute both diurnal and nocturnal species. Reef-associated fish and octopus compose a large portion of the diet (DeLong et al. 1984; Goodman-Lowe 1998; Kenyon and Rice 1959). Most seals focus foraging efforts in the top 100 m of the water column, although some seals dive to greater than 500 m deep (Parrish et al. 2002; Parrish et al. 2000; Parrish et al. 2005; Stewart et al. 2006; Wilson and D'Amico 2012).

To build a representative depth distribution for Hawaiian monk seals, data from two Stewart and Yochem (2004a, 2004b) studies were used. Figure 25 from Stewart and Yochem (2004a) and Figure 40 from Stewart and Yochem (2004b) provided time at depth for weaned pups, juveniles, and adults that could be averaged for a representative depth distribution. Stewart and Yochem (2004a, 2004b) presented depth distributions for 18 animals from Kure Atoll and Laysan Island, respectively. The maximum dive depth reported was greater than the recording limit of the tag at 490 m; therefore, 500 m is used as a conservative maximum dive depth. Most dives of all seals were shallower than 40 m and lasted less than 6 to 8 min (Stewart and Yochem 2004a, 2004b). The depth distribution for Hawaiian monk seals is given in Table 2-31.

Table 2-31. Percentage of time at depth for the Hawaiian monk seal[1]

Depth Bin (m)	% of Time at Depth
0–4	33.0
4–20	34.68
20–40	13.2
40–60	5.45
60–80	3.58
80–100	2.08
100–120	2.53
120–140	2.0
140–160	0.75
160–180	0.69
180–200	0.25
200–250	0.38
250–350	0.88
350–500	0.56

[1] Based on data from Stewart and Yochem (2004a, 2004b).

Although other studies did not include usable depth distributions for Hawaiian monk seals, they did provide additional information to categorize dive behavior. In the representative depth distribution above, 92 percent of the monk seals' time is spent within the top 100 m. This is consistent with other studies that have demonstrated Hawaiian monk seal foraging occurring at shallow reef sites (DeLong et al. 1984; Littnan et al. 2004; Parrish et al. 2000; Schlexer 1984; Wilson and D'Amico 2012; Wilson et al. 2017a; Wilson et al. 2017b).

2.2.2.3.4 *Phoca hispida*, Ringed Seal

Ringed seals have a circumpolar distribution within Arctic waters. Ringed seals are associated with continental shelf waters, and occasionally associated with deep Arctic Basin waters (Von Duyke et al. 2020). Ringed seals mainly inhabit waters with sea ice in winter months and mainly inhabit open water without sea ice in the fall (Crawford et al. 2019; Von Duyke et al. 2020). Primary prey species include arctic cod, amphipods, and crustaceans (Labansen et al. 2007; Wathne et al. 2000).

To build a representative depth distribution for ringed seals, data from Figure 3 in Gjertz et al. (2000a) were used, along with a surface bin taken from Lydersen (1991). Gjertz et al. (2000a) reported the percentage of dives to different depths for seven ringed seals. These data from Gjertz et al. (2000a) will be used as a proxy for the percentage of time spent at depth. Gjertz et al. (2000a) found that 48 percent of all dives were shallower than 20 m and 90 percent of dives were shallower than 100 m. Because the percentage of time spent at the surface was not calculated in Gjertz et al. (2000a), the Lydersen (1991) data were used to estimate this time. The Lydersen (1991) data are from a single female ringed seal over a 6-day period. If the percentage of time at the surface (30.3 percent) from Lydersen (1991) is used as an estimate, and the percentage of dives is taken as a proxy for the percentage of time, then the following representative depth distribution results. The remaining bins of the Gjertz study were redistributed proportionally to account for the remaining 69.7 percent of non-surface time. The resulting depth distribution profile includes data from both studies. The depth distribution for ringed seals is given in Table 2-32.

Table 2-32. Percentage of time at depth for the ringed seal[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–1	30.3	30–40	4.88
1–4	9.76	40–50	4.18
4–8	13.24	50–100	14.64
8–12	5.23	100–150	5.58
12–16	3.49	150–200	1.39
16–20	1.39	200–300	0.34
20–30	5.58		

[1] Based on data from Gjertz et al. (2000a) and Lydersen (1991).

Although other studies generally did not include usable depth distributions for ringed seals, they did provide additional information to categorize dive behavior. These dive depths are consistent with Wathne et al. (2000), who found that ringed seals feed on shallower prey than harp seals, which make 35 percent of their dives to deeper than 100 m. Adult ringed seals in the Arctic region were recorded as diving to depths of almost 300 m (Von Duyke et al. 2020), between 100 and 150 m (Crawford et al. 2019), and between 80 and 100 m (Everett et al. 2018). Crawford et al. (2019) found more than 57 percent of dives by adults and juveniles were between 2 and 10 m, and juveniles on rare occasions reached depths between 300 and 350 m. Results from other studies are mostly consistent with the representative dive profile.

2.2.2.3.5 *Phoca largha*, Spotted Seal

Spotted seals occur in cold temperate and polar waters of the North Pacific and Arctic Oceans, including the Yellow Sea, East China Sea, Sea of Japan, Sea of Okhotsk, Bering Sea, and Chukchi Sea (Jefferson et al. 2015; Yang et al. 2023). They are found either in the open ocean or in pack ice habitats throughout the year, including the ice over continental shelves during the winter and spring. They haul out on sea ice, but they also come ashore on land during the ice-free seasons of the year. Their range contracts and expands in correlation to ice cover, with their distribution being the most concentrated during the colder winter months. When the ice cover recedes in the Bering Sea, some seals migrate northward into the Chukchi and Beaufort Seas. As ice cover increases in the northern waters of their range, seals migrate southward through the Chukchi and Bering Seas to maintain ice association. Peak haul-out times are during molting and pupping months from February to May (Burns 2009). Prey species include a variety of pelagic and benthic fish (e.g., rockfish, sand lance, pollock) and cephalopods (Dehn et al. 2007; Takano et al. 2023).

Little data have been collected on the dive behavior of the spotted seal. Dives as deep as 300 to 400 m have been reported for adult spotted seals, with pups diving to 80 m (Bigg 1981). London et al. (2014) noted that most seal dives were to depths less than 70 m, but dives from 70 to 200 m were observed primarily during the late winter and spring. Lowry et al. (1994) reported that seals in the Chukchi Sea dove to depths less than 100 m, with a limited number of dives longer than 10 min in duration.

Due to the lack of available data on the dive behavior of spotted seals, they will be represented by a surrogate species: the harbor seal (Section 2.2.2.3.6). The spotted seal is closely related to the harbor seal (Burns 2009). Harbor seals' maximum dive depths are up to 454 m which is in the range of the deepest dives performed by spotted seals (maximum dive of 400 m) (Bigg 1981; Bowen et al. 1999; Gjertz et al. 2001). Harbor seals spend the majority of their time in the top 70 m (heavily weighted in the top 10 m), similar to spotted seals (Bowen et al. 1999; Gjertz et al. 2001; London et al. 2014). The depth distribution for the harbor seal can be found in Table 2-33.

2.2.2.3.6 *Phoca vitulina*, Harbor Seal

Harbor seals are found in shallow inshore and coastal waters of the Northern Hemisphere (Burns 2002). Prey species include epibenthic and benthic fish (e.g., sand lance, flounder, and herring) and squid (Brown and Mate 1983; Olesiuk 1993; Payne and Selzer 1989).

To build a representative depth distribution for harbor seals, data from Figure 3 in Gjertz et al. (2001) and an activity budget from Bowen et al. (1999) were used. Gjertz et al. (2001) studied the dive behavior of 14 harbor seals, with 10 having dive depth and duration recordings, in Svalbard, Norway. Figure 3 shows dive-depth and dive-duration frequencies; thus, these data from Gjertz et al. (2001) will be used as a proxy for the percentage of time spent at depth. The activity budget from Bowen et al. (1999) provided a surface time of 85.01 percent. The remaining bins from Gjertz et al. (2001) were redistributed proportionally to account for the remaining 14.99 percent of non-surface time. The resulting depth distribution profile includes data from both studies. The depth distribution for harbor seals is given in Table 2-33.

Table 2-33. Percentage of time at depth for the harbor seal[1]

Depth Bin (m)	% of Time at Depth
0-10	85.04
10–20	2.10
20–40	3.94
40–60	1.80
60–90	1.78
90–120	1.36
120–150	1.35
150-200	0.79
200-250	0.57
250-300	0.58
300-350	0.55
350-400	0.10
400-452	0.04

[1] Based on data from Gjertz et al. (2001) and Bowen et al. (1999).

Although other studies did not include usable depth distributions for harbor seals, they did provide additional information to categorize dive behavior. Studies have reported shallower maximum dive depths, reaching less than 100 m off Svalbard (Heide-Jorgensen et al. 2001), and in Prince William sound (Frost et al. 2001). Womble et al. (2014) found that harbor seals dive most frequently (81.6 percent of the time) to depths shallower than 50 m. Hastings et al. (2004) observed that less than 6 percent of harbor seals dive to depths greater than 100 m, although one seal dove to 508 m (Hastings et al. 2004). Eguchi and Harvey (2005) observed that males dive deeper than females, with males diving to depths shallower than 154 m and females diving to depths shallower than 76 m for 95 percent of the time. Results from other studies are mostly consistent with the representative dive profile.

2.2.3 Sirenians

2.2.3.1 Family Dugongidae

2.2.3.1.1 *Dugong dugon*, Dugong

Dugongs are a tropical sirenian species found in shallow, coastal waters where seagrasses are prevalent. They prefer protected bays and channels but can occur farther from shore over the shelf (Jefferson et al. 2015). Dugongs primarily feed on seagrass (Marsh et al. 2018; Prajapati et al. 2022), though macro-invertebrates and algae also contribute to their overall diet (Marsh et al. 2018).

To build a representative depth distribution for dugongs, data from the text of Chilvers et al. (2004) were used. The data were recorded in waters of northern Australia for 15 dugongs. Dugongs were tagged and tracked for an average of 10.4 days. Dugong dive depth and durations were also recorded (Chilvers et al. 2004). The depth distribution for dugongs is given in Table 2-34.

Table 2-34. Percent of time at depth for the dugong[1]

Depth Bin (m)	% of Time at Depth
0–1.5	47.0
1.5–3	25.0
3–21	27.0
21–200	1.0

[1] Based on data from Chilvers et al. (2004).

Although other studies did not include usable depth distributions for dugongs, they did provide additional information to categorize dive behavior. Dugongs have been recorded diving from less than 1 to 36.5 m (Churchward 2001; Hodgson 2004; Sheppard et al. 2006). Dugongs often travel in the water column or at the bottom rather than at the surface (Sheppard et al. 2006). The data from these studies align with the maximum dive depths in the representative dive profile.

2.3 CONCLUSIONS

The recommended static depth distributions are provided for 54 marine animal species occurring within the SURTASS LFA Sonar Training and Testing Study Area. These distributions, especially those that rely on surrogates, should be updated periodically as new data become available. Also, for most species, only a single depth distribution is presented; ideally, each species should have multiple distributions available, depending on the behavior and age/sex class of the animals being modeled as well as the geographic location and season in which the simulation occurs. More detailed depth distribution data will permit improved realism for the scenarios being modeled.

3. MARINE MAMMAL GROUP SIZE INFORMATION

3.1 INTRODUCTION

Many marine mammals are known to travel and feed in groups. NAEMO accounts for this behavior by incorporating species-specific group sizes into the modeled animat (i.e., a virtual animal) distributions and by accounting for statistical uncertainty around the group size estimate. Group sizes are handled differently in each modeling site, based on data availability and the recommendations of the research groups that provide the density information. The vast majority of group size data were derived from the same survey and observation data that were used to develop the Navy Marine Species Density Database models and were delivered to NUWC Division Newport in the appropriate format by the density providers. Exceptions to this exist for the pinnipeds (bearded, ribbon, Hawaiian monk, ringed, spotted, and harbor seals) and dugong. Alternative density estimates were used for these species and are essentially calculated as an in-water abundance divided by an area. Densities for pinnipeds and the dugong relied on published data on the abundance, occurrence, and distribution of the species, including data from telemetry studies if available, that enabled the Navy to define spatial strata with greater precision and to better represent species' distribution than in previous analyses (refer to Section 1.2.2. in DoN (2024)).

3.2 SURTASS LFA SONAR TRAINING AND TESTING STUDY AREA GROUP SIZES

Group size data for the SURTASS LFA Sonar Training and Testing Study Area are presented in Table 3-1. These data may be provided by species or guild, depending on the density data available. For those species for which only alternative density estimates were available (i.e., pinnipeds, dugong), a constant distribution of "1" was used; therefore, these species are not included in Table 3-1.

Table 3-1. Mean group size, standard deviation, and ranges for marine mammals in the SURTASS LFA Sonar Training and Testing Study Area

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Modeling Site 1: East of Japan				
Baird's beaked whale	15.2	0.73	NA	Log-normal
Blue whale	1.23	NA	1–2.81	Poisson
Bryde's whale	1.48	NA	1–4.31	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.181	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Dall's porpoise	5.01	1.7	1–220	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	1.48	NA	1–2.31	Poisson
Ginkgo-toothed beaked whale	2.13	0.56	1–4.8	Poisson
Hubbs' beaked whale	2.05	0.05	1–5	Poisson
Humpback whale	1.35	NA	1–65.81	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Melon-headed whale	196.2	2.4	2–3,000	Log-normal
North Pacific right whale	1.44	NA	NA	Poisson
Northern right whale dolphin	67.09	1.54	1–500	Log-normal
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Sei whale	1.81	NA	1–2.21	Poisson
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Stejneger's beaked whale	2.05	0.05	1–5	Poisson
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 2: North Philippine Sea				
Blainville's beaked whale	1.7	0.6	1–2.3	Poisson
Blue whale	1.23	NA	1–2.81	Poisson
Bryde's whale	1.48	NA	1–4.31	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	1.48	NA	1–2.3[1]	Poisson
Fraser's dolphin	106.2	0.35	NA	Log-normal

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Ginkgo-toothed beaked whale	2.13	0.56	1–4.8	Poisson
Humpback whale	1.35	NA	1–65.8[1]	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	196.2	2.4	2–3,000	Log-normal
Omura's whale	1.48	NA	1–4.3[1]	Poisson
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 3: West Philippine Sea				
Blainville's beaked whale	1.7	0.6	1–2.3	Poisson
Blue whale	1.23	NA	2.8–2.8	Poisson
Bryde's whale	1.51	0.06	1–2.7	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Deraniyagala's beaked whale	2.13	0.56	1–4.8	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin Whale	2.3	NA	2.3–2.3	Poisson
Fraser's dolphin	106.2	0.35	NA	Log-normal
Ginkgo-toothed beaked whale	2.13	0.56	1–4.8	Poisson
Humpback whale	2.6	0.14	1–65.8	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	196.2	2.4	2–3,000	Log-normal
Omura's whale	1.51	0.06	1–2.7	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 4: Offshore Guam				

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Blainville's beaked whale	3.35	0.27	2.7–4	Poisson
Blue whale	2.8	NA	2.8–2.8	Poisson
Bryde's whale	1.95	0.53	1–4.3	Poisson
Common bottlenose dolphin	10.25	0.76	5.2–24	Log-normal
Common minke whale	1	NA	1–1	Poisson
Goose-beaked whale	2.5	0.2	2–3	Poisson
Deraniyagala's beaked whale	1.64	0.57	1–3.5	Poisson
Dwarf sperm whale	1	NA	1–1	Poisson
False killer whale	8.21	0.94	1.5–26.2	Log-normal
Fin whale	2.3	NA	2.3–2.3	Poisson
Fraser's dolphin	106.2	0.35	NA	Log-normal
Ginkgo-toothed beaked whale	1.64	0.57	1–3.5	Poisson
Humpback whale	2.60	0.14	1–65.8	Poisson
Killer whale	5.5	1.04	1–40	Log-normal
Longmans beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	169.75	0.7	87.1–399.3	Log-normal
Omura's whale	1.95	0.53	1–4.3	Poisson
Pantropical spotted dolphin	33.91	0.81	1.7–115.2	Log-normal
Pygmy killer whale	8.1	0.37	6–10.2	Log-normal
Pygmy sperm whale	1	NA	1–1	Poisson
Risso's dolphin	4.83	0.76	1–8.3	Log-normal
Rough-toothed dolphin	12.64	0.55	7.3–15.7	Log-normal
Sei whale	1.21	0.34	1–2.2	Poisson
Short-finned pilot whale	25.09	0.58	5–51.4	Log-normal
Sperm whale	5.11	0.9	1–18.6	Log-normal
Spinner dolphin	22.49	1.17	4–98.3	Log-normal
Striped dolphin	25.26	0.56	7–50.7	Log-normal
Modeling Site 5: Sea of Japan				
Baird's beaked whale	15.2	0.73	NA	Log-normal
Bryde's whale	1.48	NA	1–4.3[1]	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Dall's porpoise	5.01	1.7	1–220	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	1.48	NA	1–2.3[1]	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Omura's whale	1.48	NA	1–4.3[1]	Poisson
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Stejneger's beaked whale	2.05	0.05	1–5	Poisson
Striped dolphin	94.76	1.37	1–1500	Log-normal
Modeling Site 6: East China Sea				
Blainville's beaked whale	1.7	0.6	1–2.3	Poisson
Blue whale	2.8	NA	2.8–2.8	Poisson
Bryde's whale	1.51	0.06	1–2.7	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	2.3	NA	2.3–2.3	Poisson
Fraser's dolphin	106.2	0.35	NA	Log-normal
Ginko-toothed beaked whale	2.13	0.56	1–4.8	Poisson
Humpback whale	2.60	0.14	1–65.8	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	196.2	2.4	2–3,000	Log-normal
Omura's whale	1.51	0.06	1–2.7	Poisson
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 7: South China Sea				
Blainville's beaked whale	3.35	0.27	2.7–4	Poisson
Blue whale	2.8	NA	2.8–2.8	Poisson
Bryde's whale	1.95	0.53	1–4.3	Poisson
Common bottlenose dolphin	10.25	0.76	5.2–24	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2	NA	1–5.1[1]	Poisson
Deraniyagala's beaked whale	3	NA	1–4.8[1]	Poisson
Dwarf sperm whale	1	NA	1–1	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	3	NA	1–2.3[1]	Poisson
Fraser's dolphin	6.33	NA	NA	Log-normal
Ginkgo-toothed beaked whales	3	NA	1–4.8[1]	Poisson

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Humpback whale	2.60	0.14	1–65.8	Poisson
Killer whale	5.5	1.04	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	7.33	0.91	3–15	Log-normal
Omura's whale	1.95	0.53	1–4.3	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	Log-normal
Pygmy sperm whale	1	NA	1–1	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	12.64	0.55	7.3–15.7	Log-normal
Short-finned pilot whale	44.7	0.95	7–200	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	11.5	1.05	3–20	Log-normal
Striped dolphin	8.75	NA	NA	Log-normal
Modeling Site 8: Offshore Japan (25 to 40 Degrees North)				
Baird's beaked whale	15.2	0.73	NA	Log-normal
Blainville's beaked whale	1.7	0.6	1–2.3	Poisson
Blue whale	1.23	NA	1–2.8[1]	Poisson
Bryde's whale	1.48	NA	1–4.3[1]	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common dolphin	83.03	1.28	1–680	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Dall's porpoise	5.01	1.70	1–220	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	1.48	NA	1–2.3[1]	Poisson
Ginko-toothed beaked whale	2.13	0.56	1–4.8	Poisson
Hubb's beaked whale	2.05	0.05	1–5	Poisson
Humpback whale	1.35	NA	1–65.8[1]	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	196.20	2.4	2–3,000	Log-normal
Northern right whale dolphin	67.09	1.54	1–500	Log-normal
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	24.4	0.36	NA	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Sei whale	1.81	NA	1–2.2[1]	Poisson
Short-finned pilot whale	59.68	2.03	1–1500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Stejneger's beaked whale	2.05	0.05	1–5	Poisson

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Modeling Site 9: Offshore Japan (10 to 25 Degrees North)				
Blainville's beaked whale	3.35	0.27	2.7–4	Poisson
Blue whale	2.8	NA	2.8–2.8	Poisson
Bryde's whale	1.95	0.53	1–4.3	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Goose-beaked whale	2.5	0.2	2–3	Poisson
Deraniyagala's beaked whale	1.64	0.57	1–3.5	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	2.3	NA	2.3–2.3	Poisson
Fraser's dolphin	106.2	0.35	NA	Log-normal
Ginkgo-toothed beaked whale	1.64	0.57	1–3.5	Poisson
Humpback whale	2.6	0.14	1–65.8	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	196.2	2.4	2–3,000	Log-normal
Omura's whale	1.95	0.53	1–4.3	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	8.1	0.37	6–10.2	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	39.06	0.78	2–120	Log-normal
Sei whale	1.21	0.34	1–2.2	Poisson
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	5.11	0.9	1–18.6	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Sites 10 and 11: Hawaii North and South				
Blainville's beaked whale	1.7	0.6	1–2.3	Poisson
Blue whale	2.8	NA	2.8–2.8	Poisson
Bryde's whale	1.51	0.06	127	Poisson
Common bottlenose dolphin (Pelagic stock)	22.3	0.19	1–111.5	Log-normal
Common minke dolphin	1	NA	1–1	Poisson
Goose-beaked whale	2.2	0.8	1–5.1	Poisson
Dwarf sperm whale	2.7	0.3	2.3–3.5	Poisson
False killer whale (Northwestern Hawaiian Islands Stock)	19	0.46	1.7–52	Log-normal
False killer whale (Pelagic stock)	5.58	0.14	1–26.07	Log-normal
Fin whale	2.3	NA	2.3–2.3	Poisson
Fraser's dolphin	359.6	0.3	291.9–427.3	Log-normal
Humpback whale	2.6	0.14	1–65.8	Poisson

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Killer whale	4.9	NA	4.9–4.9	Log-normal
Longman's beaked whale	15	0.4	6.8–22.6	Log-normal
Melon-headed whale	187.9	0.5	86.4–246.2	Log-normal
Pantropical spotted dolphin (Big Island stock)	75.43	0.2	2.3–426.3	Log-normal
Pantropical spotted dolphin (Four-Island stock)	54.63	0.36	4.7–97.8	Log-normal
Pantropical spotted dolphin (Oahu stock)	87.27	0.08	79.4–101.5	Log-normal
Pantropical spotted dolphin (pelagic stock)	71.90	0.14	4.3–312.4	Log-normal
Pilot whale	27.96	0.08	2.3–178.3	Log-normal
Pygmy killer whale	14.6	0.4	10.8–18.4	Log-normal
Pygmy sperm whale	1.4	0.5	1–2.3	Poisson
Risso's dolphin	21.36	0.12	2.2–60.4	Log-normal
Rough-toothed dolphin	23.62	0.1	3–80.8	Log-normal
Sei whale	3.1	1	1–5.1	Poisson
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	47.7	1	9.3–125.8	Log-normal
Striped dolphin	44.18	0.1	1–219.9	Log-normal
Modeling Site 12: Offshore Sri Lanka				
Blainville's beaked whale	2	0.53	1–2.3[1]	Poisson
Blue whale	1.6	NA	1–14	Poisson
Bryde's whale	1	NA	1–1	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	3	NA	1–5.1[1]	Poisson
Deraniyagala's beaked whale	2	0.53	1–4.8[1]	Poisson
Dwarf sperm whale	3	NA	1–6	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fraser's dolphin	183.32	0.57	NA	Log-normal
Ginkgo-toothed beaked whale	2	0.53	1–4.8[1]	Poisson
Indo-Pacific bottlenose dolphin	10.25	0.76	NA	Log-normal
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	7.2	1.15	1–40	Log-normal
Melon-headed whale	283.3	0.97	NA	Log-normal
Omura's whale	1	NA	1–1	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	15.81	0.44	NA	Log-normal
Pygmy sperm whale	3	NA	1–6	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	21.4	0.7	NA	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	11.2	NA	1–35	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 13: Andaman Sea				
Blainville’s beaked whale	2	0.53	1–2.3[1]	Poisson
Blue whale	1.6	NA	1–14	Poisson
Bryde’s whale	1	NA	1–1	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	3	NA	1–5.1[1]	Poisson
Deraniyagala’s beaked whale	2	0.53	1–4.8[1]	Poisson
Dwarf sperm whale	3	NA	1–6	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fraser’s dolphin	183.32	0.57	NA	Log-normal
Ginkgo-toothed beaked whale	2	0.53	1–4.8[1]	Poisson
Indo-Pacific bottlenose dolphin	10.25	0.76	NA	Log-normal
Indo-Pacific humpback dolphin	3.75	0.64	1–40	Log-normal
Indo-Pacific finless porpoise	2.6	0.11	1–10[1]	Poisson
Irrawaddy dolphin	5	0.1	2–15	Log-normal
Killer whale	5.5	1.05	1–40	Log-normal
Longman’s beaked whale	7.2	1.15	1–40	Log-normal
Melon-headed	283.3	0.97	NA	Log-normal
Omura’s whale	1	NA	1–1	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	15.8	0.44	NA	Log-normal
Pygmy sperm whale	3	NA	1–6	Poisson
Risso’s dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	21.4	0.7	NA	Log-normal
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	11.2	NA	1–35	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 14: Northwest of Australia				
Antarctic minke whale	1.18	NA	1–1.18[1]	Poisson
Blainville’s beaked whale	2	0.53	1–2.3[1]	Poisson
Blue whale/Pygmy blue whale	1.55	0.54	1–7	Poisson
Bryde’s whale	1	NA	1–1	Poisson
Common bottlenose dolphin	59.44	1.52	1–500	Log-normal
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	3	NA	1–5.1[1]	Poisson
Dwarf sperm whale	3	NA	1–6	Poisson
False killer whale	27.19	2.11	1–500	Log-normal
Fin whale	2.3	NA	2.3–2.3	Poisson
Fraser’s dolphin	183.32	0.57	NA	Log-normal
Humpback whale	2.6	0.14	1–65.8	Poisson

Species	Mean Group Size	Coefficient of Variation	Range (no. of animals)	Distribution Used
Killer whale	5.5	1.05	1–40	Log-normal
Longman's beaked whale	7.2	1.15	1–40	Log-normal
Melon-headed whale	283.3	0.97	NA	Log-normal
Omura's whale	1	NA	1–1	Poisson
Pantropical spotted dolphin	154.63	1.66	1–2,500	Log-normal
Pygmy killer whale	15.8	0.44	NA	Log-normal
Pygmy sperm whale	3	NA	1–6	Poisson
Risso's dolphin	23.06	2.18	1–1,000	Log-normal
Rough-toothed dolphin	21.4	0.7	NA	Log-normal
Sei whale	3.1	1	1–5.1	Poisson
Short-finned pilot whale	59.68	2.03	1–1,500	Log-normal
Sperm whale	9.5	0.1	1–41	Log-normal
Spinner dolphin	90.3	1.54	1–1,000	Log-normal
Striped dolphin	94.76	1.37	1–1,500	Log-normal
Modeling Site 15: Northeast of Japan				
Baird's beaked whale	15.2	0.73	NA	Log-normal
Blue whale	1.23	NA	1–2.8[1]	Poisson
Common minke whale	1.18	NA	1–1.18[1]	Poisson
Goose-beaked whale	1.99	0.06	1–5	Poisson
Dall's porpoise	5.01	1.70	1–220	Poisson
Fin whale	1.48	NA	1–2.3[1]	Poisson
Humpback whale	1.35	NA	1–65.8[1]	Poisson
Killer whale	5.5	1.05	1–40	Log-normal
North Pacific right whale	1.44	NA	NA	Poisson
Northern right whale dolphin	67.09	1.54	1–500	Log-normal
Pacific white-sided dolphin	127.66	2.37	1–2,360	Log-normal
Sei whale	1.81	NA	1–2.2[1]	Poisson
Sperm whale	9.5	0.1	1–41	Log-normal
Stejneger's beaked whale	2.05	0.05	1–5	Poisson

[1] The minimum group size was assumed to be one.

NA = non-applicable.

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