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Dive Distribution and Group Size Parameters for Marine Species Occurring in the U.S. Navy's Gulf of Alaska Study Area

Jocelyn R. Borcuk
Monica L. DeAngelis
NUWC Division Newport

Erin M. Oliveira
Melissa R. Chalek
Jason S. Krumholz
Emily E. Skeehan
McLaughlin Research Corporation

NEWPORT

Naval Undersea Warfare Center Division Newport, Rhode Island

PREFACE

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 species. This report recommends species-typical static depth distributions and group size information for all marine mammal and sea turtle species that occur in the Gulf of Alaska (GOA) Training and Testing Study Area that will be modeled using NAEMO.

Technical reviewers for the information within this report were Monica L. DeAngelis and Tara E. Moll (Naval Undersea Warfare Center Division, Newport), Chip Johnson (Command Pacific Fleet) and Laura Busch (United States Fleet Forces), Andrew D. DiMatteo (McLaughlin Research Corporation), and Dawn Grebner (Naval Undersea Warfare Center Division, Keyport).

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Jocelyn R. Borcuk and Monica L. DeAngelis
NUWC Division, Newport
Erin M. Oliveira, Melissa R. Chalek, Jason S. Krumholz, and Emily E. Skeehan
McLaughlin Research Corporation

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EXECUTIVE SUMMARY

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 species. This report recommends species-typical static depth distributions and group size information for all marine mammal and sea turtle species that occur in the Gulf of Alaska (GOA) Study Area that will be modeled using NAEMO.

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LIST OF ABBREVIATIONS AND ACRONYMS

DTAG	Digital Acoustic Recording Tag
E AK	Eastern Alaska
GOA	Gulf of Alaska
m	Meter(s)
min	Minute(s)
°N	Degrees North
NAEMO	Navy Acoustic Effects Model
NMFS	National Marine Fisheries Service
NUWC	Naval Undersea Warfare Center
SD	Standard Deviation
TDR	Time-Depth Recorder
U.S.	United States
USFWS	U.S. Fish and Wildlife Services
W AK	Western Alaska

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 and sea turtles to be used within the Navy Acoustic Effects Model (NAEMO).

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 and permanent threshold shifts), and other injuries predicted for individual marine mammals and sea turtles likely to be in the vicinity of Navy training and testing activities.

1.2 Data Inputs

NAEMO first uses location-specific density (more detailed information regarding species density is available in the Gulf of Alaska Temporary Maritime Activities Area density technical report (U.S. Department of the Navy 2020)) and group size information 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 four minutes throughout the simulation, based on the depth distribution for that species. When available, seasonal or geographically-specific depth and group size information is used.

In addition to available marine mammal and sea turtle 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 and sea turtles. This 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 the Quantitative Analysis Technical Report (U.S. Department of the Navy 2018).

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2. Marine Mammal and Sea Turtle Depth Distributions

The best available science from literature reviews was used to obtain species-specific depth distribution information for the Gulf of Alaska (GOA) Training and Testing Study Area (Figure 1). Journal articles, books, technical reports, cruise reports, funding agency reports, theses, dissertations, and raw data from individual researchers were assessed for this report.

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 (U.S. Department of the Navy 2020).

The information required for representing a species in NAEMO specifically focuses on the percent 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. Depth distributions contain percent time spent in the water only, either at the surface or in given depth bins. 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. Rather than round down to zero, the deep bins are often rounded up 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).

2.1 Surrogate Species and Study Areas

Depth distribution data within this report are based upon species-specific tagging data obtained during literature review. If tagging data were not available for a particular species, 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 (i.e., within the same genus or family), feeds on similar prey, or has a distribution in similar water types (e.g., continental shelf waters). Surrogate species (if required) for all species are provided in Table 1 for the GOA Study Area.

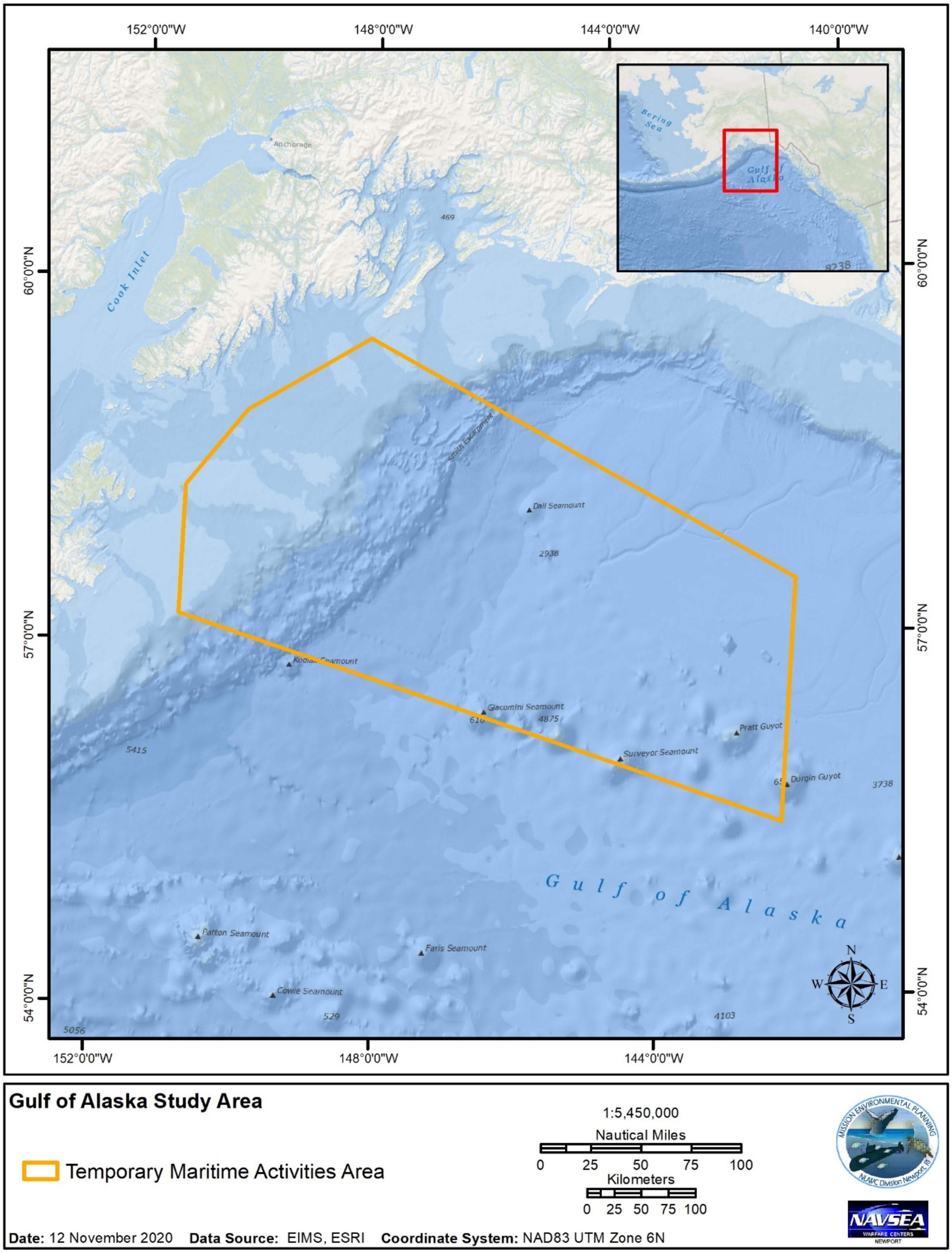

Figure 1. Gulf of Alaska Study Area

Table 1. Marine Mammal and Sea Turtle Species Occurring in the GOA 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 borealis	Sei whale	Bryde's whale (*Balaenoptera edeni*)	2.2.1.1.2
Balaenoptera musculus	Blue whale	N/A	2.2.1.1.3
Balaenoptera physalus	Fin whale	N/A	2.2.1.1.4
Eubalaena japonica	North Pacific right whale	North Atlantic right whale (*Eubalaena glacialis*)	2.2.1.1.5
Megaptera novaeangliae	Humpback whale	N/A	2.2.1.1.6
Family Delphinidae			
Orcinus orca	Killer whale	N/A	2.2.1.2.1
Lagenorhynchus obliquidens	Pacific white-sided dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.2
Family Eschrichtiidae			
Eschrichtius robustus	Gray whale	N/A	2.2.1.3.1
Family Phocoenidae			
Phocoena phocoena	Harbor porpoise	N/A	2.2.1.4.1
Phocoenoides dalli	Dall's porpoise	N/A	2.2.1.4.2
Family Physeteridae			
Physeter macrocephalus	Sperm whale	N/A	2.2.1.5.1

Table 1. Marine Mammal and Sea Turtle Species Occurring in the GOA Study Area (Cont'd)

Species Name	Common Name	Surrogate species	Section
Family Ziphiidae			
Berardius bairdii	Baird's beaked whale	Cuvier's beaked whale	2.2.1.6.1
Mesoplodon stejnegeri	Stejneger's beaked whale	Blainville's beaked whale (*Mesoplodon densirostris*)	2.2.1.6.2
Ziphius cavirostris	Cuvier's beaked whale	N/A	2.2.1.6.3
Sea Otters			
Family Mustelidae			
Enhydra lutris kenyoni	Northern sea otter	N/A	2.2.2.1.1
Pinnipeds			
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
Zalophus californianus	California sea lion	N/A	2.2.2.2.3
Family Phocidae			
Histriophoca faciata	Ribbon seal	N/A	2.2.2.3.1
Mirounga angustirostris	Northern elephant seal	N/A	2.2.2.3.2
Phoca vitulina	Harbor seal	N/A	2.2.2.3.3
Sea Turtles			
Family Dermochelyidae			
Dermochelys coriacea	Leatherback sea turtle	N/A	2.2.3.1.1

2.2 Marine Mammal and Sea Turtle Dive Behavior Summaries

This section discusses the depth distributions that were constructed for each species or surrogate species, based on the best available science. Ideally, depth distributions would be specific to different locations; however, sometimes diving data were not available for the precise locations within GOA. Marine mammal and sea turtle 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 between depth bins. For each species, a distribution throughout the water column is presented, along with a list of the references that are the sources of these data and an explanation of 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).

2.2.1 Cetaceans

2.2.1.1 Family Balaenopteridae

2.2.1.1.1 *Balaenoptera acutorostrata*, Common Minke Whale

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 minke whale diet (Haug et al. 1995). Minke whales feed by side-lunging into schools of prey as well as by gulping large amounts of water (Jefferson et al. 2008).

Little data have been collected on the dive behavior of minke whales. In order to build a representative depth distribution for 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 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 minutes [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 each of these two behaviors can vary significantly among individuals (Blix and Folkow 1995). The depth distribution for common minke whales is given in Table 2.

Table 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 is capable of diving to greater depths than depicted by this distribution. For example, minke whales in the Antarctic have been associated with krill patches found at a median depth of 118 m (Friedlaender et al. 2009b). Off Scotland, minke whales are found where patches of pre-spawning herring occur at depths between 100 and 150 m (MacLeod et al. 2003), while off the coast of California, tagged minke whales dove to 130 m (Southall et al. 2014), although in both cases whales spend the majority of 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). In general, like other marine mammals, dives can be categorized based on behavior. For minke whales in St. Lawrence, Canada, these categories were surface feeding, foraging at depth, and non-feeding (i.e., traveling or resting). Dive depth when feeding varied according to the depth at which prey could be found (Christiansen et al. 2015). The longest dives conducted by the minke whales in this study were between 10 and 12 min long (Christiansen et al. 2015). After a long dive, minke whales must conduct several short dives in order to breathe and replenish oxygen stores. The depth distribution shown in Table 2 will be considered representative for common minke whales until more information becomes available.

2.2.1.1.2 *Balaenoptera borealis*, Sei Whale

Sei whales have a cosmopolitan distribution, migrating between high-latitude feeding grounds and low-latitude breeding grounds (Horwood 2002). 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 (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. The maximum dive depth of two whales tagged in the western North Pacific was 57 m, though the mean maximum dive depths of the two whales were 19 m during the day and 12 m at night (Ishii et al. 2017). The mean dive durations were approximately three minutes, with the longest dives occurring during the daytime, which supports that dive depths of sei whales coincide with changes in the dense scattering layers of their prey (Ishii et al. 2017). 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.

Due to the limited duration of tag attachment and the small sample size in available data on the dive behavior of sei whales (Ishii et al. 2016; Ishii et al. 2017), they will be represented by a surrogate species: the Bryde's whale. 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). While 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 and spend 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 order 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 to 40–292 m includes time passing through the 0–40 m depth bin), these data are the best available approximation of time spent at depth. The depth distribution for sei whales is given in Table 3.

Table 3. Percentage Time at Depth for the Sei Whale[1,2]

Depth Bin (m)	% of Time at Depth
0–40	84.5
40–292	15.5

[1]Based on data from Alves et al. (2010)
[2]This depth distribution uses the Bryde's whale as a surrogate species

2.2.1.1.3 *Balaenoptera musculus*, 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).

In order to build a representative depth distribution for blue whales, data from Figures 4 and 8 in Oleson et al. (2007), as well as Figure 2 from Acevedo-Gutiérrez et al. (2002) were used. Oleson et al. (2007) provided graphs of the percent time at depth of 38 blue whales off the coast of California in Figure 8. The data for the non-vocal, AB callers (pulsed and tonal calls), and D callers (downsweeping sounds) were averaged together to get a general depth distribution. However, 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 percent 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 time. The depth distribution for blue whales is given in Table 4.

Table 4. 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	20.9	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	205–215	1.1
55–65	3.5	215–225	1.1
65–75	2.8	225–235	1
75–85	2.2	235–245	0.9
85–95	2.4	245–255	0.7
95–105	2.4	255–265	0.7
105–115	2.1	265–275	0.3
115–125	2	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)

As with many rorqual species, blue whales spend more time diving to shallow depths at night, and diving deeper during the day, due to the vertical migration of their prey (Calambokidis et al. 2019; Mate et al. 2015). 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 Monterey 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), 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. 2015; 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 4. While, four whales tagged in the Gulf of Corcovado, Chile, dove to a maximum depth of 139 m (average depths of most dives ranging between 10 and 50 m) the shallow depths of dives were presumed to be where prey were located in this location (Bocconcelli et al. 2015). The maximum dive depth logged by Lewis et al. (2018) was 351 m (deeper than the maximum dive recorded by Acevedo-Gutiérrez et al. (2002)),but most dives recorded were not deeper than 315 m which is consistent with Table 4.

2.2.1.1.4 *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 (Nottestad et al. 2002), and cephalopods (Flinn et al. 2002). A 2019 study has shown that elevated areas of prey productivity are more dispersed offshore, while nearshore these areas of elevated productivity are in locations of physically forced upwelling; therefore, bouts of feeding that occur in offshore areas are farther apart than those in coastal areas (Irvine et al. 2019). Fin whale feeding bouts may contain anywhere from four to over a hundred dives (Irvine et al. 2019), according to tag data.

In order 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) were used as a proxy for 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 deeper than 50 m were 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 5.

Table 5. 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)

While 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 527 m (Acevedo-Gutiérrez et al. 2002; Goldbogen et al. 2006; Irvine et al. 2019; Mate et al. 2016) have been recorded. In the Ligurian Sea, a maximum dive to over 470 m was noted (Panigada et al. 1999).While Southall et al. (2014) reported that dives by fin whales rarely exceed 250 m, Keen et al. (2019) recorded maximum dive depths of 10 fin whales ranging between 247 and 527 m. The median depth of these dives, however, ranged from 29–87 m (Keen et al. 2019). These data are consistent with the depth distribution in Table 5. As with many rorqual species, fin whales spend more time diving to shallow depths at night, and diving deeper during the day, due to the vertical migration of their prey (Calambokidis et al. 2019). Keen et al. (2019) also found that both daytime and nighttime dives during summer were deeper than in winter.

2.2.1.1.5 *Eubalaena japonica*, North Pacific Right Whale

The North Pacific right whale is the rarest of all large whale species (Wade et al. 2011), with a population that is likely less than 100 individuals and potentially as low as 26 whales (Wade et al. 2011). They are distributed from temperate to polar latitudes, with most sightings occurring in the Bering Sea. Sightings have ranged from central Baja California in the eastern North Pacific, to Hawaii in the central North Pacific, and to the northern waters of the Bering Sea in the summer. The summer range of the eastern stock of North Pacific right whales includes the GOA and the Bering Sea (while the western stock is believed to feed in the Okhotsk Sea and in pelagic waters of the northwestern North Pacific). However, there have been far fewer sightings of right whales in the GOA than in the Bering Sea (Brownell et al. 2001). Unlike most other baleen whales, right whales are skimmers: they feed with their mouth open moving through patches of zooplankton. Their primary food sources are copepods, euphausiids, and cyprids.

Given that this whale is difficult to find and observe, North Pacific right whales have only rarely been tagged. Satellite transmitters were deployed on five individual North Pacific right whales in 2004, 2008, and 2009 with the goal of discovering space-use patterns in the Southeastern Bering Sea (Zerbini et al. 2015). The whales were monitored for an average of 40 days (ranging from 29−58 days) between July and October. The use of habitats from 50–100 m was dominant in the Bering Sea critical habitat area;

however, dive data were not examined. Therefore, little is known about the dive behavior of North Pacific right whales.

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.

In order 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 time within 3 m of the surface, while Nowacek and McGregor (2010) reported whales spent on average 32.89 percent of 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 6.

Table 6. Percentage of Time at Depth for the North Pacific 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 uses the North Atlantic right whale as a surrogate species.

Dive depths on Atlantic foraging grounds are consistent with the depth of feeding reported by Baumgartner and Mate (2003), with dives typically to prey at depths of 80–175 m. While Baumgartner et al. (2017) found that the North Atlantic right whales in their study spent, on average, 75 percent of their time in the upper 10 m of the water column, this study had very short tag durations—roughly half were on the animals for more than 30 minutes.

2.2.1.1.6. *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). Humpback whales have been shown to dive to and feed on the densest region of the krill layer (Burrows et al. 2016).

Due to a separation of behaviors based on location within a foraging ground or within a breeding ground, a separate representative depth distribution was compiled for humpback whales within foraging grounds. In order to build a representative depth distribution for humpback whales within foraging grounds, data from Figure 3.8 as well as the text of Dietz et al. (2002) were used. Dietz et al. (2002) shows the number of dives per hour to specific depth bins. The data from Dietz et al. (2002) were used as a proxy for percentage of time spent at depth for the six whales tagged off the foraging grounds of West Greenland. While Figure 3.8 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 7.

Table 7. Percentage of Time at Depth for the Humpback Whales on Foraging Grounds[1]

Depth Bin (m)	% of Time at Depth
0–8	79.2
8–20	11.5
20–35	2.7
35–50	1.0
50–100	1.6
100–150	1.4
150–200	1.2
200–300	1.2
300–400	0.2

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

Dive depths on the Greenland foraging grounds are consistent with the depth of feeding reported by Goldbogen et al. (2008) off central California and Dolphin (1987b) off Alaska. Dolphin (1987a); however, 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. Calambokidis et al. (2019) examined dives off California and found that humpback whales spent anywhere from 69–88 percent of their time in the top 30 m, depending on time of day. A study of humpback whale dive behavior in Antarctica found that traveling dives were to a mean depth of 41 m and foraging dives were to a mean depth of 194 m. In this study, the deepest observed dive was 543 m (Weinstein et al. 2018); however, this was thought to be an investigation of the water column's prey density (Weinstein et al. 2018), which would vary by location, season, and time of day. While the depth distribution in Table 7 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 7 is consistent with these studies as well. Off the coast of southeast Alaska, average dive duration was 7.56 min (Burrows et al. 2016), though this may be a result of both the overall water depth in the area and the depth at which humpback whales fed.

2.2.1.2 Family Delphinidae

2.2.1.2.1 *Orcinus orca*, Killer Whale

Killer whales have a cosmopolitan distribution, but they 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 Alaska, as in other locations, 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). Four killer whale stocks are recognized in the GOA Study Area: 1) the Alaska Resident stock, which occurs from southeast Alaska to the Bering Sea; 2) the Gulf of Alaska, Aleutian Islands, and Bering Sea Transient stock, which occurs from Prince William Sound through the Aleutian Islands to the Bering Sea; 3) the AT1 Transient stock, which occurs from Prince William Sound through the Kenai Fjords; and 4) the offshore stock.

Due to a separation of diving behaviors based on preferred prey of the killer whale, two separate representative depth distributions were compiled for killer whales: fish-eating killer whales and mammal-eating killer whales. 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 (Domenici et al. 2000; Nøttestad et al. 2002). 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 that occurred during the day.

In order 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), as well as 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 (Table 8). 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. The depth distribution for fish-eating killer whales is given in Table 8. The deepest killer whale dive recorded thus far was to 264 m by Baird et al. (2005a), who tagged a total of 34 Southern Resident killer whales. However, the average of all the tagged killer whale deepest dives was 141 m, which is consistent with the depth distribution in Table 8 below. This depth distribution will be used for the Alaska Resident; the Gulf of Alaska, Aleutian Islands, and Bering Sea Transient; and the offshore stocks of killer whales.

Table 8. 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)

While other studies did not include depth distributions for killer whales, they did provide additional information to categorize dive behavior. In a study of tagged Southern Resident killer whales, which are fish-eaters that consume Chinook salmon (*Oncorhynchus tshawytscha*), it was noted that these salmon were typically pursued at depths greater than 30 m. This same study determined that each whale spent the greatest proportion of time conducting dives that were categorized as shallow to intermediate and associated with a variety of behaviors (Tennessen et al. 2019). In a study of tagged Northern Resident killer whales, which are fish-eaters that consume various species of Pacific salmon, it was noted that 82 percent of foraging dives were to depths of more than 100 m (Wright et al. 2017). Another tagging study examines the depredation of toothfish longlines by killer whales (Towers et al. 2019), but this diving behavior is specific to this foraging method, which is not present for killer whales off the coast of Alaska.

In order to build a representative depth distribution for mammal-eating killer whales (Table 9), data from Figure 5 in Miller et al. (2010) and Figure 2.5B from Baird (1994) were used. Based on visual inspection and interpretation of the figure provided by Miller et al. (2010), an average dive distribution was created for the presented whales; visual inspection was also used to build a depth distribution from the figure presented by Baird (1994). The calculated data from Miller et al. (2010) was weighted by a factor of 11 when creating the final dive profile for mammal-eating killer whales, due to the presence of 11 animals in that study compared to one presented by Baird (1994). This depth distribution will be used for the AT1 Transient stock of killer whales.

Table 9. Percentage of Time at Depth for Mammal-Eating Killer Whales[1]

Depth Bin (m)	% of Time at Depth
0–10	42.9
10–20	23.4
20–30	14.0
30–40	8.3
40–50	6.0

Depth Bin (m)	% of Time at Depth
50–60	2.5
60–70	1.7
70–80	0.8
80–100	0.4

[1]Based on data from Baird (1994) and Miller et al. (2010)

2.2.1.2.2 *Lagenorhynchus obliquidens*, Pacific White-sided Dolphin

Pacific white-sided dolphins inhabit cold temperate waters of the North Pacific, in both offshore and coastal waters (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 seconds in duration, and dives longer than 90 seconds were rare, indicating that most dives are shallow. Heise (1997) similarly reported that 70 percent of foraging dives were less than 15 seconds 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. More recent data do exist, but these data are also based on trained animals (e.g., Tanaka et al. 2019), and thus, not suitable for assessing behavior of Pacific white-sided dolphins in the wild.

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. 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.

In order 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. While 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 two meter intervals for the top 10 meters. For the Baird et al. (2001) nighttime and Scott and Chivers (2009) data, the percentage of time determined for the top 10 meters was uniformly distributed across these two meter 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 10. 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 Pacific white-sided dolphins is given in Table 10.

Table 10. Percentage of Time at Depth for the Pacific White-Sided Dolphin[1,2]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–2	20.3	70–80	0.6
2–4	10.6	80–90	0.6
4–6	8.6	90–100	0.4
6–8	9.0	100–110	0.3
8–10	9.5	110–120	0.3
10–20	21.2	120–130	0.1
20–30	8.8	130–140	0.1
30–40	3.8	140–150	0.1
40–50	2.5	150–160	0.1
50–60	1.9	160–170	0.1
60–70	1.1		

[1]Based on data from Baird et al. (2001) and Scott and Chivers (2009)
[2]This depth distribution uses the pantropical spotted dolphin as a surrogate species

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 used to capture neritic fish, and scraping 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 whales forage in waters less than 20 m deep in many areas (Guerrero 1989; Ljungblad et al. 1987; Malcolm and Duffus 2000; Malcolm et al. 1995; Stewart et al. 2001; Woodward and Winn 2006).

In order to build a representative depth distribution for gray whales, data from Figure 3 in Malcolm et al. (1995) were used. Malcom 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 breathing at the surface or feeding at the bottom. Due to the large size of gray whales, the data from Malcom et al.

(1995) was summed into four-meter bins for the representative depth distribution. The depth distribution for gray whales is given in Table 11.

Table 11. 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 Malcom et al. (1995)

While 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 12–19 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 0–2 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 the that in the representative depth distribution. In the Chukchi Sea, Brower et al. (2017) found that the highest densities of feeding gray whales were located in waters less than 50 m deep.

2.2.1.4 Family Phocoenidae

2.2.1.4.1 *Phocoena phocoena*, Harbor Porpoise

Harbor porpoises inhabit temperate and sub-arctic 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).

In order 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 et al. (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 that average dive depth for individual porpoises ranged from 14–41 m, and the depth range with the greatest proportion of dives was 2–10 m. Otani et al. (1998) found that harbor porpoises off the coast of Japan spent 74–86 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 into the dive distribution. While data from Cooper (1993), Otani (1998), and Westgate et al. (1995) show the number or frequency of dives to specific depth bins, this data will be used as a proxy for percentage of time spent at depth. The depth distribution for harbor porpoises is given in Table 12.

Table 12. 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	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	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. (1995)

A study by Nielsen et al. (2019), showed a higher percentage of deep dives by harbor porpoises, including dives as deep as 250 m, which is slightly deeper than the deepest bin in Table 12. However, the authors note that in this study water depth and prey availability created a circumstance where it was beneficial for the harbor porpoises to dive to more than 200 m, but that this is not "normal" dive behavior for the species. Therefore, these deeper data were not incorporated into the depth distribution in Table 12.

While other studies did not include depth distributions for harbor porpoises, they did provide additional information to categorize dive behavior. In 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 that harbor porpoises spent more time between 0 to 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 [*Clupea harengus*] and sprat [*Sprattus sprattus*]) (Cardinale et al. 2003).

2.2.1.4.2 *Phocoenoides dalli*, Dall's Porpoise

Dall's porpoises can be found in the subarctic and cool temperate waters of the 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).

In order 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 197–278 m. Data from the tagged Dall's porpoises were averaged together to create the representative depth distribution in Table 13.

Table 13. 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
5–6	1.7	100–110	1.1
6–7	1	110–120	0.7
7–8	1.3	120–130	0.4
8–9	1.3	130–140	0.4
9–10	1.7	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 suggests that Dall's porpoises feed high in the water column on vertically migrating mesopelagic species but occasionally forage on deeper benthic prey (Jefferson 1988; Ohizumi et al. 1998). A more recent partial profile by Hooker and Baird (2001) and limited qualitative data from a more recent review by Jarvis et al. (2014) are consistent with the depth distribution in Table 13.

2.2.1.5 Family Physeteridae

2.2.1.5.1 *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 North (°N) 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).

To account for published differences in the foraging dive behavior of whales in different regions, separate depth distributions were generated for the Atlantic Ocean, Gulf of Mexico, and the Pacific Ocean. In general, time spent at depth for the regions is consistent with foraging dives to 800–1,200 m in the Western North Atlantic Ocean (Sivle et al. 2012; Teloni et al. 2008; Watwood et al. 2006), and 400–1,300 m in the Western North Pacific Ocean (Amano and Yoshioka 2003; Aoki et al. 2012; Aoki et al. 2007). Overall, sperm whales typically spend 70–80 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 30–50 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. While 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 14.

Table 14. Percentage of Time at Depth for the Sperm Whale[1]

Depth Bin (m)	% of Time at Depth
1–50	30.2
51–100	4.8
101–150	3.3
151–200	3.3
201–250	3.1
251–300	2.5
301–350	2.5
351–400	3.6
401–450	5.3
451–500	6.5
501–600	9.8
601–700	6.5
701–800	8.6
801–900	8.4
901–1000	1.3
1001–1100	0.3

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

While other studies did not include depth distributions for sperm whales, they did provide additional information to categorize dive behavior. In a study that compared the dive data of tagged first-year whales and adults, the maximum dive depths of calves ranged from 285–662 m. Calves spent 43 percent of their time performing dives beyond 50 m, while adults spent a median of 76 percent of their time performing dives beyond 50 m (Tønnesen et al. 2018). In a tagging study in the Gulf of California, Mexico, the mean maximum dive depth was 325 m, but reached depths of more than 1,500 m occasionally, and the mean duration was 25.4 min (Irvine et al. 2017). This study showed that on many deep dives, the sperm whale followed the bottom topography. Irvine et al. (2017) also stated that roughly one third of the recorded time was spent at the surface, which aligns with the depth distribution in Table 14.

2.2.1.6 Family Ziphiidae

2.2.1.6.1 *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 2002; Walker et al. 2002).

Little data have been collected on the dive behavior of Baird's beaked whales. A passive acoustic monitoring study confirmed the distribution of Baird's beaked whales in cold-temperate waters around the GOA at a depth of 1,000 m (Baumann-Pickering et al. 2014). Stomach contents analysis suggests that whales are feeding at depths of 800–1,200 m off Japan, feeding on prey at or near the seafloor (Reeves et al. 2002; Walker et al. 2002). Minamaka (2007) reported that one animal carrying a time-depth recorder dove down to a maximum depth 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 (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: Cuvier's beaked whale (Section 2.2.1.6.3). The Cuvier's 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 16.

2.2.1.6.2 *Mesoplodon stejnegeri*, Stejneger's Beaked Whale

The Stejneger's beaked whale inhabits cold, temperate, and subarctic waters of the North Pacific Ocean and southwest Bering Sea (Ellis and Mead 2017; Loughlin et al. 1982; Loughlin and Perez 1985). This species tends to be distributed in deep, offshore waters on or beyond the continental slope, in water depths ranging from 730–1,560 m (Baumann-Pickering et al. 2013). Like other beaked whales, the Stejneger's beaked whale is a pelagic, deep-diving forager with short surface intervals in between long dives (Tyack et al. 2006). Loughlin et al. (1982) found that these whales make a series of five to six short dives, followed by a longer dive lasting 10–15 min (Baumann-Pickering et al. 2013). The Stejneger's beaked whale feeds mainly on squid, though they may also eat smaller fish and shrimp.

Because Stejneger's beaked whales have rarely been sighted at sea, most information comes from stranding data (Jefferson et al. 2008). As a result, little dive data exists for this species. Due to the lack of data on the diving behavior of the Stejneger's beaked whale, it will be represented by a surrogate species: Blainville's beaked whale. Like Stejneger's beaked whales, Blainville's beaked whales are deep divers and feed on small fish and cephalopods (e.g., squid). Both Stejneger's and Blainville's beaked whales usually make regular dives of 20 minutes in duration and commonly reach depths of at least 488–1,006 m, but dives of over 54 minutes and up to 1,433 m have also been recorded (NOAA Fisheries 2020). In Baird (2019), it was noted that Cuvier's beaked whales are found in deeper water, and dive deeper, than Blainville's beaked whales. While Cuvier's beaked whales are located within the GOA Study Area (vice Blainville's beaked whales which are not), the depth distribution for Blainville's beaked whales is used because Blainville's beaked whales spend a greater percentage of time in the upper 100 m of water than Cuvier's beaked whales, making the model a more conservative estimate of affected beaked whales.

In order 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 (2008b) and Johnson and Aguilar de Soto (2008a), DTAG data from Tyack (2010), and Figure 1b from Tyack et al. (2006). Arranz et al (2011) tagged 9 whales to collect acoustic and movement data, looking to study buzz and click behaviors during dives; Figures 3a and 3b 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 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 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 (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 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 Stejneger's beaked whales is given in Table 15.

Table 15. Percentage of Time at Depth for the Stejneger's Beaked Whale[1,2]

Depth Bin (m)	% of Time at Depth
1–100	54.3
100–200	10.2
200–300	3.7
300–400	3.2
400–500	3.7
500–600	3.4
600–700	3.7
700–800	4.1
800–900	4.7
900–1,000	3
1,000–1,100	2.2
1,100–1,200	1.8
1,200–1,300	1.1
1,300–1,400	0.8
1,400–1,500	0.1

[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 (Johnson and Aguilar de Soto 2008a, 2008b), Tyack et al. (2006), and Tyack (2010)
[2] This depth distribution uses the Blainville's beaked whale as a surrogate species

2.2.1.6.3 *Ziphius cavirostris*, Cuvier's Beaked Whale

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 content analyses indicate that prey species include mesopelagic and benthic cephalopods, fish, and crustaceans (Heyning 1989; Hickmott 2005; Santos et al. 2001). It appears, however, that Cuvier's beaked whales eat mostly squid, and the majority of prey are open-ocean species that occur well below the surface, including on or near the seafloor in deep waters (Reeves et al. 2002).

In order to build a representative depth distribution for the Cuvier's beaked whale (Table 16), data were acquired from 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 (Johnson and Sturlese 2008a, 2008b), 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 Cuvier's 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 Cuvier's 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 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 (Johnson and Sturlese 2008a, 2008b), were binned. Kvadsheim et al. (2012) presented changes in dive behavior in response to sonar; as this report is portraying normal Cuvier's 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 calculated typical depth distribution. Schorr et al. (2014) provided multi-day tag data for Cuvier's 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 below. The depth distribution for Cuvier's beaked whales is given in Table 16.

Table 16. Percentage of Time at Depth for Cuvier's Beaked Whale[1,2]

Depth Bin (m)	% of Time at Depth
0–100	32
100–200	10.3
200–300	11.7
300–400	5.6
400–500	4.1
500–600	3.9
600–700	5.1
700–800	4.1
800–900	3.5
900–1,000	4.8
1,000–1,100	4.4
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. (2006), Baird et al. (2005b), Baird et al. (2006), Baird et al. (2008), Barlow et al. (2013), Johnson and Sturlese (Johnson and Sturlese 2008a, 2008b), Kvadsheim et al. (2012), and Schorr et al. (2014)

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

This representative depth distribution is consistent with foraging dives from 689 to 1,888 m in the Mediterranean Sea (Tyack et al. 2006) and to 1,450 m off Hawaii (Baird et al. 2006). Based on the representative depth distribution in Table 16, Cuvier's beaked whales spent 31.9 percent of their time between 0–100 m and 36.1 percent of time deeper than 500 m; these values remain consistent with the data reported by Baird et al. (2008), in which Cuvier's beaked whales spend 12.4–51.1 percent of their time spent at depths less than 50 m, and between 33.9–52.1 percent of time at depths greater than 500 m. Studies by Quick et al. (2020), and Falcone et al. (2017) provide qualitative discussion of dive parameters that roughly mirror the depth distribution in Table 16. The Quick study reports dive frequencies, and dive and inter-dive intervals that support the general assertion that roughly half of the Cuvier's beaked whale's time is spent at the surface or in shallow inter-dive intervals, while roughly half is spent making deeper foraging dives (Quick et al. 2020). Falcone et al. shows that the timing and duration of deep diving bouts during control periods (when not exposed to sonar, which is the primary focus of the study) align with the depth distribution in Table 16 (Falcone et al. 2017).

2.2.2 Carnivores

2.2.2.1 Family Mustelidae

2.2.2.1.1 *Enhyra lutris*, Northern Sea Otter

The sea otter ranges around the North Pacific Ocean rim, from Baja California, Mexico to the east coast of the Russian Kamchatka peninsula and the Kuril Islands towards 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 (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). 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. Laidre et al. (2009) found that adult females spent 60 percent of their time foraging in habitats no more than 10 m deep and were rarely found foraging in waters 30 m deep. Males in the same study spent most of their time (32–34 percent) foraging in habitats 10–30 m deep. Beyond 40 m, foraging was minimal (1–2 percent of time) for both sexes (Laidre et al. 2009).

While dive data is 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 bathymetry in the areas where dive data was logged. In the GOA Study Area, sea otters would occupy similar depths. While 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.

In order to build a representative depth distribution for the northern sea otter, the activity budget in Laidre et al. (2009) was used and adjusted for time spent underwater. According to Laidre et al. (2009), 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. (2009) classified “other” behavior (similar to (Gelatt et al. 2002)), as grooming, swimming, or any active non-feeding behavior. Bodkin et al. (2004) describe this type of behavior as “traveling dives” and measured these as averaging around 2.7 m. Therefore, in Table 17, the 0–5 m bin includes time spent underwater while traveling, participating in “other” behavior, and foraging. The total percentage of time spent in the 0–5 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 northern sea otters is given in Table 17.

Table 17. Percentage of Time at Depth for the Northern 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. (2009)

While many studies did not include depth distributions for northern sea otters, they did provide additional information to categorize dive behavior. Early studies of sea otter dive behavior assumed average dives to be within 10–30 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 sea otters in Alaska, but focused primarily on those with dependent pups.

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 state (Laidre and Jameson 2006) reported an average foraging dive time of 0.9 min (54 seconds), 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 seconds for individual foraging dives (Bodkin et al. 2004; Thometz et al. 2016; Wolt et al. 2012).

Several studies have created activity budgets for sea otters (Bodkin et al. 2007; Esslinger et al. 2014; Wolt 2014; Yeates et al. 2007), but the data from Laidre et al. (2009) is the most robust, utilizing the behavior of 25 sea otters; therefore this was used in the depth distribution in Table 17. Females tend to rest 1,000 m offshore (42 percent of their resting time) and were rarely observed resting beyond 2,000 m offshore (Laidre et al. 2009). Males tended to rest 1,000–1,500 m offshore 40 percent of the time and 2,000–2,500 m offshore 11 percent of the time (Laidre et al. 2009).

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, including the Bering Sea, Sea of Okhotsk, and Sea of Japan, ranging coastally as far south as Baja, California, Mexico, and Japan, and with an at-sea southern limit around 35°N (Gelatt and Lowry 2008). Northern fur seals are known to feed in the deep waters along the continental shelf break, as well as in shallower waters of the shelf itself

(Gentry 2002; Ponganis et al. 1992). The diet of northern fur seals varies regionally and seasonally, but it is comprised 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 and Estes 1990).

In order to build a representative depth distribution for the Northern fur seals, data from Table 1 in Kooyman et al. (1976) were used. The dive behavior and physiology of the northern fur seal was among the earliest pinniped species to be tagged and tracked (Kooyman et al. 1976). Table 1 in Kooyman et al. (1976) indicates the number of dives to specific depth bins; these data will be used as a proxy for percentage of time spent at depth. Kooyman et al. (1976) found that shallow dives (0–20 m) lasted less than 1 min in duration. Deeper dives, from 20–140 m, lasted from 2–5 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 18.

Table 18. 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)

While 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 the vast majority of their lives at sea (87–90 percent of the year), only coming ashore to breed for 35–45 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; Gentry 2002; Goebel et al. 1991; Kooyman et al. 1976; Kuhn et al. 2009b; Kuhn et al. 2010; 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 prey types (Gentry et al. 1986).

Female northern fur seals dive mostly at night (68 percent) (Gentry et al. 1986). 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). A thesis study by Sterling supports the assertion that dive depths of northern fur seals are driven by oceanographic and prey distribution factors, and that, overall, the largest frequency of dives are between 17.5–37.5 m, with approximately 50 percent of overall time spent within these water depths. Although the depth bin is different than that displayed in Table 18, the study supports a similar conclusion that northern fur seals spend most of their time foraging at shallow depths of less than 50 m (Sterling 2009). In addition, 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 the maximum depth of a given dive is most frequently between 50 and 60 m (Gentry et al. 1986) and deeper foraging dives do not typically exceed 120–170 m (Goebel et al. 1991). The activity budgets for adult females on foraging trips was 17 percent of time spent resting, 26 percent of time spent diving, and 57 percent of time spent in surface active time (Gentry et al. 1986). These data are consistent with the depth distribution in Table 18.

Male northern fur seal diving behavior has also been examined (Sterling and Ream 2004) and has revealed that like parturient females, juvenile males exhibit shallow versus deep dive patterns based upon 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).

2.2.2.2.2 *Eumetopias jubatus*, Steller Sea Lion

Steller sea lions inhabit the Pacific Ocean north of approximately 30°N latitude (Loughlin 2002; Schusterman 1981). They feed on an assortment of shallow water fish, cephalopods, bivalves, and crustaceans (Schusterman 1981; Tollit et al. 2004).

Rehberg et al. (2009) reported on the summer diving behavior of five adult sea lions belonging to the Eastern Alaska (E AK) stock. They also summarized similar data on four Western Alaska (W AK) stock females from Merrick (1995) and Merrick and Loughlin (1997). A dive was counted as any movement of the animal below 4 m depth. Visual inspection of Figure 2 and the text from Rehberg et al. (2009) results in the distribution of dive depths in Table 19.

Table 19. Dive Depth Distribution Data from Rehberg et al. (2009), Merrick (1995), and Merrick and Loughlin (1997) Used to Estimate Depth Distribution for the Steller Sea Lion

Depth Bin (m)	Percentage of Dives		
	E AK Stock	W AK Stock	Average
4–-10	45	35	40
10–20	14	46	30
20–50	23.5	15	19.25
50–100	14	3	8.5
100–250	3.5	1	2.25
>250	0	0	0

Due to the lack of data on time spent at depth, the data in Table 19 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 in Table 19 will be adjusted to represent 22.1 percent of an animal's time, with 77.9 percent of time spent between depths of 0-4 m. The maximum dive depth reported in this study was 236 m, and the last dive bin is adjusted to reflect this. The resulting depth distribution is given in Table 20.

Table 20. Percentage of Time at Depth for the Stellar 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), Merrick (1995), and Merrick and Loughlin (1997)

The ratios of time spent submerged are generally supported by a study by Volpov et al. (2016) using trained animals. The depth distribution in Table 20 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; Skinner et al. 2012). It is shallower than the maximum reported dive depth of 328 m by a juvenile sea lion (Loughlin et al. 2003). 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 northern fur seals dive aligns with the presence of prey. Though prey abundance is seasonally and geographically variable, the general assertion that northern fur seals spend the majority of their time in the top 50 m of the water column is consistent (Sigler et al. 2009).

2.2.2.2.3 *Zalophus californianus*, California Sea Lion

California sea lions primarily breed on island beaches off southern California—along Baja California, Mexico, and in the Gulf of California (Heath 2002). California sea lions have been documented at several locations in Alaska (Maniscalco et al. 2004), including in southeast Alaska and near the Kenai Peninsula in Prince William Sound. This species has been documented as far north as St. Paul Island in the Bering Sea. In total, 52 California sea lions were documented in this region between 1963 and 2003, and they were observed during all seasons of the year (Maniscalco et al. 2004). Their presence in the GOA Study Area is likely extremely low, both due to the rare nature of the occurrence and the species preference for nearshore habitat. California sea lions eat a variety of prey, including schooling fish, crustaceans, and cephalopods (García-Rodríguez and Aurioles-Gamboa 2004; Melin et al. 2008; Porras-Peters et al. 2008). California sea lions often make shallow dives in some coastal areas for epipelagic prey and deeper dives in others, such as in the Gulf of California, for mesopelagic prey (Costa et al. 2004; Lowry and Carretta 1999; Melin and DeLong 1999).

In order to build a representative depth distribution for California sea lions, data from Figure 4 in Feldkamp et al. (1989) and Figure 1a in Weise (2006) were used. Both figures show the number of dives to specific depth bins; thus, the data from Feldkamp et al. (1989) and Weise (2006) will be used as a proxy for percentage of time spent at depth. Because data indicate differences in diving behavior between males (Weise 2006) and females (Feldkamp et al. 1989; Kuhn 2006; Melin et al. 2008), data from Weise (2006) and Feldkamp et al. (1989) were averaged to create a composite distribution. Weise (2006) reported an average dive depth of 32 m, but most dives occurred within the depth range of 10 to 20 m. Feldkamp et al. (1989) found that the maximum dive depth for females was roughly 274 m. The mean depths ranged from 31 to 98 m, but the majority of dives went to between 20 and 50 m. In order to account for the time spent at the surface, an activity budget from Table 3 in Thomas et al. (2010) was used, incorporating both male and female sea lions. Based on these numbers, a percent time swimming at the surface (63.62 percent) was added into the average taken from the Feldkamp et al. (1989) and

Weise (2006) data. The remaining averages from both studies were redistributed proportionally to account for the remaining 36.38 percent of time. The resulting depth distribution profile includes data from all three studies. The depth distribution for California sea lions is given in Table 21.

Table 21. Percentage of Time at Depth for the California Sea Lion[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	68.3	120–130	0.5
10–20	5.9	130–140	0.4
20–30	6	140–150	0.5
30–40	4.8	150–160	0.5
40–50	4	160–170	0.5
50–60	2.3	170–180	0.3
60–70	1.5	180–190	0.1
70–80	1	190–200	0.1
80–90	0.7	200–210	0.2
90–100	0.7	210–220	0.1
100–110	0.7	220–230	0.1
110–120	0.6	230–500	0.2

[1]Based on data from Feldkamp et al. (1989), Weise (2006), and Thomas (2010)

While other studies did not include usable depth distributions for California sea lions, they did provide additional information to categorize dive behavior. Mean dive depths reported for female California sea lions range from 45–70 m with maximum dive depths ranging from 104–279 m (Kuhn 2004; Kuhn 2006; Melin et al. 2008). While these dataset does not necessarily capture the maximum dive depths reported in several locations (greater than 200 m) (Costa et al. 2004; Feldkamp et al. 1989; Kuhn 2004; Kuhn 2006; Melin et al. 2008), the depth distribution is consistent with studies by Kuhn (2004) and Melin (2008), both of whom demonstrated that the majority of dives (ranging from 55–85 percent) were less than 50 m deep. Similarly, Melin and DeLong (1999) reported that most dives were shallower than 100 m; therefore, although the depth distribution in Table 21 may be shallower than seen in some locations, it does capture published diving behavior for the species and is representative for California sea lions. Average dive depths and durations published by DeLong et al. (2017) also fall within the ranges established in Table 21. A limited number of depth distributions collected by McDonald and Ponganis suggest mixed behavior, fluctuating between shallow dives (of less than 50 m) with shorter (1–2 minute) surface intervals and deeper dives (to 300 m or more) with longer (more than 10 minute) surface intervals (McDonald and Ponganis 2013). During these deeper diving intervals, California sea lions may spend as much as 5–10 percent of their time at depths greater than 200 m (McDonald and Ponganis 2013). However, since these bouts of deep diving are sporadic, and dictated by bottom depth and prey distribution, the overall estimate of less than one percent of total time spent at depths greater than 200 m (Table 21) aligns with the research of McDonald and Ponganis (2013).

2.2.2.3 Family Phocidae

2.2.2.3.1 *Histriophoca faciata*, Ribbon Seal

The ribbon seal inhabits the North Pacific Ocean and adjacent southern parts of the Arctic Ocean, including the Bering, Chukchi, and western Beaufort Seas (Boveng et al. 2013). 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, including walleye Pollock (*Theragra chalcogramma*), eelpouts, and Arctic cod (*Boreogadus saida*), 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 time-at-depth recorders deployed on ribbon seals by the National Marine Fisheries Service (NMFS) were used. The resulting depth distribution profile includes data from all deployments on ribbon seals prior to 2014. The data is unpublished and was delivered by Josh London to the Naval Undersea Warfare Center (NUWC) Division, Newport, Rhode Island. The depth distribution for ribbon seals is given in Table 22.

Table 22. Percentage of Time at Depth for the Ribbon Seal[1]

Depth Bin (m)	% of Time at Depth
0–10	34.26
10–30	10.87
30–50	10.94
50–70	9.45
70–90	8.07
90–150	13.59
150–200	4.96
200–250	3.24
250–300	2.41
300–400	1.96
400–650	0.79

[1]Based on data from personal communication with Josh London (2020)

While other studies did not include usable depth distributions for ribbon seals, they did provide additional information to categorize dive behavior. 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–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–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).

2.2.2.3.2. *Mirounga angustirostris*, Northern Elephant Seal

Northern elephant seals are limited to the North Pacific Ocean, with breeding haul outs located along the western coast of North America from northern California to Baja California and Mexico. Seals utilize deep waters for foraging, traveling north and west from breeding beaches and traveling as far north as the Gulf of Alaska and Aleutian Islands (Hindell 2002). Elephant seals feed primarily on vertically migrating epipelagic and mesopelagic squid, but they eat a variety of prey species, including elasmobranchs, crustaceans, cephalopods, and fish (DeLong and Stewart 1991; Sinclair 1994; Stewart and Huber 1993).

In order to build a representative depth distribution for Northern elephant seals, data from DeLong and Stewart (1991), Hakoyama et al. (1994), Le Boeuf et al. (1986), and Naito et al. (1989) were used. In addition, a surface time from DeLong and Stewart (1991) was incorporated into these data. The text of DeLong and Stewart (1991) states that Northern elephant seals are submerged 86 percent of the time, leaving an above-surface time percentage of 14 percent (DeLong and Stewart 1991). Due to the lack of data on time spent at depth, the data from these sources, citing percentage of dives to specific depth bins will be used as a proxy for percentage of time spent at depth. As these data show sex differences in foraging and diving behavior (DeLong and Stewart 1991; Hakoyama et al. 1994; Le Boeuf et al. 1986; Le Boeuf et al. 1993; Naito et al. 1989), males and females were averaged together to create a representative depth distribution. In males, the data averaged from Figure 1 in Delong and Stewart (1991) and Figure 4 in Hakoyama et al. (1994) showed that 83 percent of dives took place between the surface and 500 m, most frequently occurring from 300–500 m. In females, these data averaged from Figure 1 in Le Boeuf et al. (1986), Figure 2 in Naito et al. (1989), and Figure 4 in Hakoyama et al. (1994) showed that 85 percent of dives were to depths of 300–700 m, most frequently from 400–600 m. For males, dives deeper than 500 m were unusual, whereas dives over 700 m were rare for females (DeLong and Stewart 1991; Hakoyama et al. 1994; Le Boeuf et al. 1988; Le Boeuf et al. 1986; Naito et al. 1989). Data from each figure were summed into 100 m bins and averaged together. The remaining bins of each study were averaged and redistributed proportionally to account for the remaining 86 percent of non-surface time. The resulting depth distribution profile includes data from all studies. The depth distribution for Northern elephant seals is given in Table 23.

Table 23. Percentage of Time at Depth for the Northern Elephant Seal[1]

Depth Bin (m)	% of Time at Depth
0–100	21.4
100–200	7.6
200–300	8.9
300–400	13.4
400–500	18
500–600	16.3
600–700	10
700–800	2.2
800–900	0.8
900–1000	0.5
1,000–1,100	0.5
1,100–1,200	0.4

[1]Based on data from DeLong and Stewart (1991), Hakoyama et al. (1994), Le Boeuf et al. (1986), and Naito et al. (1989)

While other studies did not include usable depth distributions for northern elephant seals, they did provide additional information to categorize dive behavior. A short study of transiting elephant seals by Davis et al. (2001) shows brief surface intervals relative to dive durations, with parabolic dive profiles down to 1,000–1,200 m, but the majority of time spent between 200–800 m. However, the duration of this study was very short and represents transiting rather than foraging. As a result, these data depict slightly less time at the surface and more time at depths greater than 800 m than the depth distribution depicted in Table 23. Elephant seals spend much of their time foraging. Robinson et al. (2012) found that the dive depths of most seals showed a clear diel pattern, consistent with targeting vertically migrating prey species. Robinson et al. (2012) found the mean dive depth to be 516 m and a mean dive duration of 23.1 min. Active-bottom dives made up the greatest percentage of dives (54.0 percent) in this study (Robinson et al. 2012). Foraging seals observed by Kuhn et al. show a similar pattern to Robinson et al. and to the profile depicted in Table 23, with maximum dive depths of 500–800 m, and surface intervals of 3–5 min between dives of approximately 20–30 min in duration (Kuhn et al. 2009a; Robinson et al. 2012). Maximum dive depths for elephant seals covered a wide range of depths, from under 1,000 m (Crocker et al. 2006; Davis et al. 2001; Davis and Weihs 2007; Le Boeuf et al. 1988) to the deepest dive ever recorded by an elephant seal at 1,747 m, which is substantially deeper than the maximum depth presented in Table 23, but likely represents only a very small portion of overall species activity (Robinson et al. 2012).

2.2.2.3.3 *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., sandlance, flounder, and herring) and squid (Brown and Mate 1983; Olesiuk 1993; Payne and Selzer 1989).

In order to build a representative depth distribution for harbor seals, data from Table 3 in Womble et al. (2014) and an activity budget from Bowen et al. (1999) were used. Womble et al. (2014) studied the dive behavior of 12 female harbor seals in Alaska. Table 3 shows the percentage of dives to specific depth bins; thus, these data from Womble et al. (2014) will be used as a proxy for percentage of time spent at depth. Seals in this study were found to dive most frequently (81.6 percent) to depths shallower than 50 m. It should be noted that this study cites the percentage of dives to certain depths, as opposed to the percentage of time spent in each depth bin, including time spent in that bin on the way to a deeper bin. However, the Womble et al. (2014) data are the best available estimates 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 Womble et al. (2014) 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 24.

Table 24. Percentage of Time at Depth for the Harbor Seal[1]

Depth Bin (m)	% of Time at Depth
0–4	85.01
4–50	12.22
50–100	2.32
100–150	0.37
150–200	0.05
200–250	0.02
250–300	0.01

[1]Based on data from Womble et al. (2014) and Bowen et al. (1999)

While other studies did not include usable depth distributions for harbor seals, they did provide additional information to categorize dive behavior. Gjertz et al. (2001) reported the maximum depth reached by harbor seals to be within the 200–350 m range; however, additional studies have reported shallower maximum dive depths, reaching less than 100 m off of Nova Scotia (Bowen et al. 1999), Svalbard (Jorgensen et al. 2001), and in Prince William sound (Frost et al. 2001). Hastings et al. (2004) observed that less than six percent of harbor seals dive to depths greater than 100 m, although one seal dove to 508 m (Hastings et al. 2004). Harbor seals near Svalbard, Norway, dove to a maximum depth of 452 m, although 50 percent of dives were shallower than 40 m, and 95 percent were to less than 250 m (Gjertz et al. 2001). 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, 95 percent of the time. Blanchet et al. published a robust dataset of seasonal harbor seal diving behavior in Artic environments that shows more frequent deep diving (200–300 m) during the winter months (Blanchet et al. 2015). However, the overall depth distribution from Blanchet et al. falls well within the range observed in the Womble and Bowen studies used in Table 24.

2.2.3 Sea Turtles

2.2.3.1 Family Dermochelyidae

2.2.3.1.1 *Dermochelys coriacea*, Leatherback Sea Turtle

The leatherback turtle is globally distributed in tropical, subtropical, and warm-temperate waters throughout the year, and throughout cooler temperate waters during warmer months (James et al. 2005a; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS) 1993). Adult leatherback turtles forage in temperate and subpolar regions in all oceans and migrate to tropical nesting beaches between 30° N and 20° South (Bleakney 1965; Brongersma 1972; Goff and Lien 1988; Threlfall 1978). The leatherback is typically associated with continental shelf habitats and pelagic environments. To a large extent, the oceanic distribution of leatherbacks may reflect the distribution and abundance of their favored prey; macro-planktonic soft-bodied animals such as jellyfish, salps, and pyrosomes (Wallace et al. 2013). It is suggested that leatherbacks make scouting dives while transiting as an efficient means for sampling prey density and perhaps also to feed opportunistically at these times (James et al. 2006b; Jonsen et al. 2007).

In order to build a representative depth distribution for leatherback turtles, data from Figure 2 as well as the text of Houghton et al. (2008) were used. Houghton et al. (2008) tagged 13 adult leatherback sea turtles at two sites over the course of four years. The data in Figure 2 accounts only for the percentage of dives made to each depth bin, rather than the percent of time spent in each bin. The text states the percent of dives were made to less than 10 m (18.9 percent), which is considered the surface bin. This representative depth distribution was created to account for several behavioral states, including post-nesting, migration, and foraging. The mean dives in this study ranged from 32.5–69.0 m. Houghton et al. (2008) found that 99.6 percent of dives were to depths shallower than 300 m with only 0.4 percent extending to greater depths. These findings support the hypothesis that deep dives are periodically employed to survey the water column for diurnally descending gelatinous prey. The depth distribution for leatherback turtles is given in Table 25.

Table 25. Percentage of Time at Depth for the Leatherback Turtle[1]

Depth Bin (m)	% of Time at Depth
0–10	18.93
10–100	65.26
100–200	14.63
200–300	0.818
300–400	0.119
400–500	0.103
500–600	0.069
600–700	0.023
700–800	0.015
800–900	0.015
900–1,000	0.007
1,000–1,100	0.004
1,100–1,200	0.001
1,200–1,280	0.006

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

While other studies did not include usable depth distributions for leatherback turtles, they did provide additional information to categorize dive behavior. The leatherback is the deepest diving sea turtle, with a recorded maximum depth of 1,280 m (Doyle et al. 2008), though most dives are much shallower, usually less than 250 m (Hays et al. 2004; Sale et al. 2006). Fossette et al. (2007) reported that eighty percent of the leatherback's time at sea is spent diving, which is in agreement with the roughly 20 percent of time in the surface bin of the representative depth distribution. Dodge et al. found that over 90 percent of the time was spent in the top 100 m of the water column, and 25 percent of time was spent at the surface (Dodge et al. 2014). Similarly, in the Atlantic, Hays et al. (2004) determined that leatherbacks spent 71–94 percent of their diving time at depths from 70 to 110 m. Daytime foraging dives off of the Canadian Atlantic coast during summer ranged between 5.5 and 97 m with a median depth of 21.5 m (Heaslip et al. 2012). Leatherbacks dive deeper and longer in the lower latitudes versus the higher (James et al. 2005a; James et al. 2005b), where they are known to dive to waters with temperatures just above freezing (James et al. 2006a; Jonsen et al. 2007). James et al. (2006b) noted that dives in higher latitudes are punctuated by longer surface intervals and much more time at the surface; individuals spend up to 50 percent of their time at or near the surface in northern foraging areas, perhaps in part to thermoregulate (i.e., bask). While transiting, leatherbacks make longer and deeper dives (Jonsen et al. 2007). During inter-nesting periods, tag data has revealed that dives are likely constrained by bathymetry adjacent to nesting sites (Hays et al. 2006; Myers and Hays 2006).

2.3 Conclusions

The recommended static depth distributions are provided for 23 marine animal species occurring within the GOA 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.

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3. Marine Mammal Group Size Information

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 animal distributions, and accounting for statistical uncertainty around the group size estimate. In order to create a set of group size data for marine mammals in the GOA Study Area, survey information was used.

Group size data were determined for the GOA Study Area. Data from all relevant sources were pooled based on individual species. The average of all mean group sizes reported by the survey data for each species were determined, as well as standard deviations associated with these means. Minimum and maximum group sizes also were determined for each species at each location. In some instances where data were lacking, data from multiple areas were combined or the geographically closest data were applied.

Group size information including mean group size, SD, and ranges is presented in Table 26. Pinnipeds, leatherback sea turtles, northern sea otters, and North Pacific right whales are primarily observed individually while at sea, and therefore are assigned a group size of 1.

Table 26. Mean Group Size, Standard Deviation, and Ranges for Marine Species in the GOA Study Area

Common and Scientific Name	Mean Group Size	SD	Range	References
Cetaceans				
Family Balaenopteridae				
Minke whale *Balaenoptera acutorostrata*	1.14	0.53	1-2	(Becker et al. 2016; Forney et al. 2015)
Sei whale *Balaenoptera borealis*	1.78	1	1-5	(Becker et al. 2016; Forney et al. 2015)
Blue whale *Balaenoptera musculus*	1.68	0.9	1-5	(Becker et al. 2016; Forney et al. 2015)
Family Balaenopteridae				
Fin whale *Balaenoptera physalus*	2.23	2.99	1-29.5	(Becker et al. 2016; Forney et al. 2015)
Humpback whale *Megaptera novaeangliae*	1.7	0.65	1-3	(Becker et al. 2016; Forney et al. 2015)
Family Delphinidae				
Pacific white-sided dolphin *Lagenorhynchus obliquidens*	25.85	32.43	1-194.4	(Becker et al. 2016; Forney et al. 2015)
Killer whale *Orcinus orca*	9	13.85	1-47.7	(Becker et al. 2016; Forney et al. 2015)
Family Eschrichtiidae				
Gray whale *Eschrichtius robustus*	2.07	1.85	1-4.2	(Becker et al. 2016; Forney et al. 2015)

Table 26. Mean Group Size, Standard Deviation, and Ranges for Marine Species in the GOA Study Area (Cont'd)

Common and Scientific Name	Mean Group Size	SD	Range	References
Cetaceans				
Family Phocoenidae				
Dall's porpoise *Phocoenoides dalli*	3.97	2.17	1-8.8	(Becker et al. 2016; Forney et al. 2015)
Harbor porpoise *Phocoena phocoena*	1.82	0.98	1-7	(Dahlheim et al. 2009; Perrin et al. 2002; Rone et al. 2010; Rugh et al. 2005; Sekiguchi et al. 2005; Stewart et al. 1987; Wade et al. 2003; Zerbini 2010)
Family Physeteridae				
Sperm whale *Physeter macrocephalus*	11.59	20.95	1-109.2	(Becker et al. 2016; Forney et al. 2015)
Family Ziphiidae				
Baird's beaked whale *Berardius bairdii*	8.08	4.35	5-14.5	(Becker et al. 2016; Forney et al. 2015)
Curvier's beaked whale *Ziphius cavirostris*	2.04	1.26	1-7	(Becker et al. 2016; Forney et al. 2015)
Stejneger's beaked whale *Mesoplodon stejnegeri*	6	0.05	1-10	(Pitman 2002)

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