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Dive Distribution and Group Size Parameters for Marine Species Occurring in the U.S. Navy's Mariana Islands Training and Testing Study Area

Stephanie L. Watwood
Jocelyn R. Borcuk
NUWC Division Newport

Erin M. Oliveira
Emily R. Robinson
McLaughlin Research Corporation

NAVSEA WARFARE CENTERS
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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 Mariana Islands Training and Testing (MITT) Study Areas that will be modeled using NAEMO.

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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 Mariana Islands Training and Testing (MITT) Study Area that will be modeled using NAEMO.

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LIST OF ABBREVIATIONS AND ACRONYMS

AFTT	Atlantic Fleet Training and Testing
DTAG	Digital Acoustic Recording Tag
HSTT	Hawaii- Southern California Training and Testing
MITT	Mariana Islands Training and Testing
NAEMO	Navy Acoustic Effects Model
NMFS	National Marine Fisheries Services
NUWC	Naval Undersea Warfare Center
SD	Standard Deviation
TDR	Time-Depth Recorder
U.S.	United States
USFWS	U.S. Fish and Wildlife Services

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 density technical reports by U.S. Department of the Navy (U.S. Department of the Navy in prep-b) 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. Where available, seasonal or geographically-specific depth and group size information is used.

Density data are not available for all taxa of concern for Navy activities (Section 2). In addition to available marine mammal 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. These environmental data include information about bathymetry, seafloor composition (e.g., rock, sand), and factors that vary throughout the year such as wind speed and sound velocity profiles. The details of Navy training and testing activities are also collected, including location, frequency, and source characteristics. For more detailed information about the NAEMO model, consult the Quantitative Analysis Technical Report (U.S. Department of the Navy in prep-a).

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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 Mariana Islands Training and Testing (MITT) 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 1.2, 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 in prep-b). 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. 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). Depth distributions contain percent time spent in the water only, either at the surface or in given depth bins.

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 (within the same genus or family), feeds on similar prey, or has a distribution in similar water types (e.g., continental shelf waters). The exception to the general surrogate selection is the two species of *Kogia* spp. (dwarf and pygmy sperm whales), for which there are no other species in their family to choose as surrogates. Therefore, a species from another family within their suborder (Odontoceti) was chosen as a surrogate. Surrogate species (if required) for all species are provided in Table 1 for the MITT Study Area.

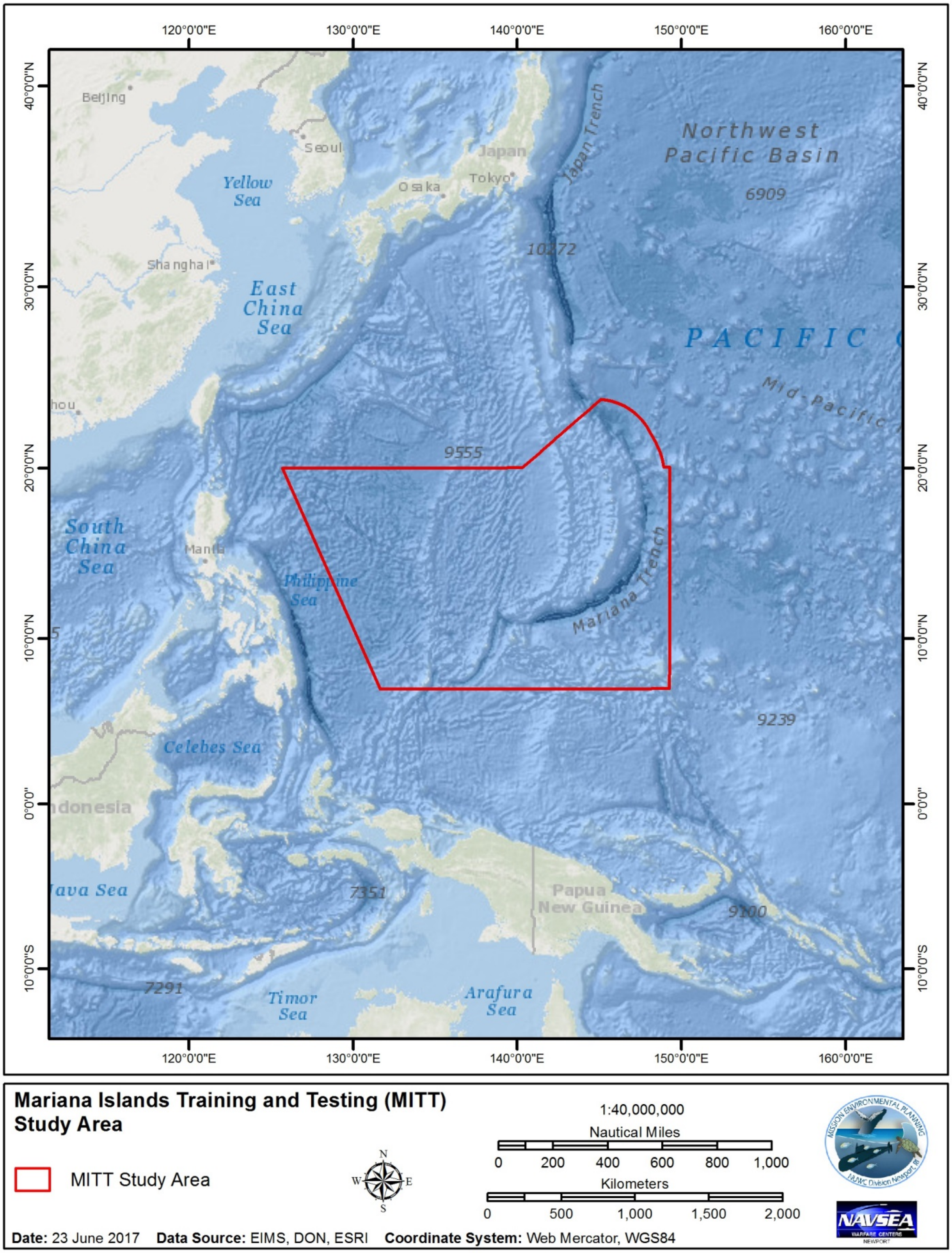

Figure 1. Mariana Islands Training and Testing Study Area

Table 1. Marine Mammal and Sea Turtle Species Occurring in the Mariana Islands Training and Testing (MITT) 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 edeni	Bryde's whale	N/A	2.2.1.1.3
Balaenoptera musculus	Blue whale	N/A	2.2.1.1.4
Balaenoptera omurai	Omura's whale	Bryde's whale (*Balaenoptera edeni*)	2.2.1.1.5
Balaenoptera physalus	Fin whale	N/A	2.2.1.1.6
Megaptera novaeangliae	Humpback whale	N/A	2.2.1.1.7
Family Delphinidae			
Feresa attenuata	Pygmy killer whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.1
Globicephala macrorhynchus	Short-finned pilot whale	N/A	2.2.1.2.2
Grampus griseus	Risso's dolphin	N/A	2.2.1.2.3
Lagenodelphis hosei	Fraser's dolphin	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.2.4
Orcinus orca	Killer whale	N/A	2.2.1.2.5
Peponocephala electra	Melon-headed whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.6
Pseudorca crassidens	False killer whale	Risso's dolphin (*Grampus griseus*)	2.2.1.2.7
Stenella attenuata	Pantropical spotted dolphin	N/A	2.2.1.2.8
Stenella coeruleoalba	Striped dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.9
Stenella longirostris	Spinner dolphin	Pantropical spotted dolphin (*Stenella attenuata*)	2.2.1.2.10
Steno bredanensis	Rough-toothed dolphin	N/A	2.2.1.2.11
Tursiops truncatus	Common bottlenose dolphin	N/A	2.2.1.2.12

Table 1. Marine Mammal and Sea Turtle Species Occurring in the Mariana Islands Training and Testing (MITT) Study Area (Cont'd)

Species Name	Common Name	Surrogate species	Section
Cetaceans			
Family Kogiidae			
Kogia breviceps	Pygmy sperm whale	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.3.1
Kogia sima	Dwarf sperm whale	Short-finned pilot whale (*Globicephala macrorhynchus*)	2.2.1.3.2
Family Physeteridae			
Physeter macrocephalus	Sperm whale	N/A	2.2.1.4.1
Family Ziphiidae			
Indopacetus pacificus	Longman's beaked whale	Blainville's beaked whale (*Mesoplodon densirostris*)	2.2.1.5.1
Mesoplodon densirostris	Blainville's beaked whale	N/A	2.2.1.5.2
Mesoplodon gingkodens	Ginkgo toothed beaked whale	Blainville's beaked whale (*Mesoplodon densirostris*)	2.2.1.5.3
Ziphius cavirostris	Cuvier's beaked whale	N/A	2.2.1.5.4
Sea Turtles			
Family Dermochelyidae			
Dermochelys coriacea	Leatherback sea turtle	N/A	2.2.2.1.1
Family Cheloniidae			
Caretta caretta	Loggerhead sea turtle	N/A	2.2.2.2.1
Chelonia mydas	Green sea turtle	N/A	2.2.2.2.2
Eretmochelys imbricata	Hawksbill sea turtle	N/A	2.2.2.2.3

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 MITT. 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 depth bin. For each species, a distribution throughout the water column is presented, along with a list of the references that are the source of the data and an explanation about how these references were used to create the distribution. Depth bins are given in meters (m). Depending on the species, the distribution may cover a larger or smaller range of depths, such as for a shallow diving odontocete 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). Individual species are listed within each order.

2.2.1 Cetaceans

2.2.1.1 Family Balaenopteridae

2.2.1.1.1 *Balaenoptera acutorostrata*, Common Minke Whale

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 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 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 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. 2009). Off Scotland, minke whales are found where patches of pre-spawning herring occur at depths between 100 and 150 m (MacLeod et al. 2003b), while off the coast of California, tagged 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). 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. 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 a lack of available data on the dive behavior of sei whales, they will be represented by a surrogate species: the Bryde's whale (Section 2.2.1.1.3). 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). The depth distribution for the Bryde's whale can be found in Table 3.

2.2.1.1.3 *Balaenoptera edeni*, Bryde's Whale

Bryde's whales are found in tropical and temperate waters, with separate coastal and offshore forms (Best 2001; Weir 2007). The main prey of Bryde's whales includes pelagic schooling fish species, such as sardines, mackerel, and herring (Siciliano et al. 2004), as well as cephalopods and small crustaceans (Kato 2002; Omura 1962).

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), the data are the best available approximation of time spent at depth. The depth distribution for Bryde's whales is given in Table 3.

Table 3. Percentage of Time at Depth for the Bryde's 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 is also representative of the sei whale

2.2.1.1.4 *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, and D callers 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	2.21
5–15	12.74	165–175	2.37
15–25	9.89	175–185	2.21
25–35	6.41	185–195	2.29
35–45	5.30	195–205	1.42
45–55	3.96	205–215	1.11
55–65	3.48	215–225	1.11
65–75	2.77	225–235	1.03
75–85	2.21	235–245	0.87
85–95	2.37	245–255	0.71
95–105	2.45	255–265	0.71
105–115	2.06	265–275	0.32
115–125	1.98	275–285	0.24
125–135	2.06	285–295	0.16
135–145	2.14	295–305	0.16
145–155	2.29	305–315	0.16

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

While other studies did not include depth distributions for blue whales, they did provide additional information to categorize dive behavior. Blue whales in the Gulf of St. Lawrence conducted foraging dives to 150 m, where feeding lunges were observed (Doniol-Valcroze et al. 2011). Similarly, a study conducted in Monterrey Bay found that blue whales fed on the most concentrated patches of krill at depths of 130-to-150 m (Schoenherr 1991). Blue whales off central California foraged at depths between 130 and 300 m (Calambokidis et al. 2008; Croll et al. 2001), while in southern California, dive depths ranged from 50 to 350 m (Acevedo-Gutiérrez et al. 2002; Croll et al. 2001; De Vos et al. 2012; Goldbogen et al. 2012; Goldbogen et al. 2013; Mate et al. 2016; Oleson et al. 2007; Southall et al. 2014). Seven whales tagged off the coast of Southern California dove to a mean depth of 140 m and a maximum depth of 204 m during foraging, while to only a mean depth of 67.6 m during non-foraging dives (Croll et al. 2001). These data are consistent with the depth distribution in Table 4.

2.2.1.1.5 *Balaenoptera omurai,* Omura's Whale

Very little is known about the ecology or behavior of Omura's whale, having only recently been confirmed to be a distinct species from the Bryde's whale (Sasaki et al. 2006; Wada et al. 2003). They have been identified primarily in tropical and subtropical waters of the Indo-Pacific, although there is grouping evidence that they may have a wider distribution (Cypriano-Souza et al. 2017; Jung et al. 2015; Ranjbar et al. 2016). Omura's whales may also reside in non-migratory, resident populations around oceanic islands (Cerchio et al. 2015). Observations over several years in Madagascar report whales located primarily on the shallow shelf waters, lunge feeding on presumably zooplankton prey (Cerchio et al. 2015).

Due to a lack of available data on the dive behavior of Omura's whales, they will be represented by a surrogate species: the Bryde's whale (Section 2.2.1.1.3). Omura's whale is most closely related to Bryde's whales, sei whales, and blue whales (Sasaki et al. 2006). Observations of whales in Madagascar revealed most sightings to be in less than 25 m of water, suggesting shallow dives, with whales foraging on zoolplankton similar to sei whales. Similarly, the Bryde's whale depth distribution has 85% of the time in the top 40 m of the water column. The depth distribution for Bryde's whales is given in Table 3.

2.2.1.1.6 *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 2001 study has shown that dense prey concentrations are typically found at depths greater than 100 m off the coast of California (Croll et al. 2001).

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) will be 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 their time in the top 50 m. Time spent at depths below 50 m were extracted from dive profiles presented in Croll et al. (2001) to represent the remaining 60 percent. The depth distribution for fin whales is given in Table 5.

Table 5. Percentage of Time 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	8.14
110–130	11.43
130–150	8.41
150–170	3.48
170–190	2.01
190–210	1.37
210–230	0.55
230–250	0.64
250–270	0.18
270–290	0.09
290–310	0.18

[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-300 m (Acevedo-Gutiérrez et al. 2002; Goldbogen et al. 2006; 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 exceeded 250 m. These data are consistent with the depth distribution in Table 5.

2.2.1.1.7 *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 sighted off Saipan exhibiting social behaviors typical of breeding grounds (Fulling et al. 2011), and song had been recorded from the Mariana Islands as well. Additionally, a cow-calf pair was sighted off Rota (Department of the Navy 2005). Therefore, humpback whales in the Mariana Islands will be presumed to behave as if on a breeding ground, although the location has not been documented as such. Humpback whales have major breeding grounds in several locations, including the West Indies, Hawaii, Mexico, and Japan (Clapham 2002). In order to build a representative depth distribution for humpback whales on breeding grounds, data from Table 3 in Baird et al. (2000) were used. Baird et al. (2000) reported the time at depth data for 10 whales in Hawaiian waters. While all 10 whales were thought to be males, the whales were engaged in a variety of behaviors, including escorting females and calves. Therefore, the depth distribution in Table 9 represents the best estimate of time spent at depth by whales on a breeding ground. Baird et al (2000) found that, on average, about 40 percent of a whale's time was spent in the top 10 m and about 90 percent of the time was spent in the top 100 m. The depth distribution for humpback whales on breeding grounds is given in Table 6.

Table 6. Percentage of Time at Depth for the Humpback Whale on Breeding Grounds[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	39.55	90–100	1.55
10–20	26.51	100–110	1.39
20–30	11.65	110–120	1.31
30–40	4.25	120–130	0.92
40–50	3.04	130–140	0.72
50–60	2.47	140–150	0.30
60–70	2.14	150–160	0.23
70–80	1.66	160–170	0.15
80–90	1.97	170–180	0.09

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

2.2.1.2 Family Delphinidae

2.2.1.2.1 *Feresa attenuata*, Pygmy Killer Whale

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

Due to a lack of available data on the dive behavior of pygmy killer whales, they will be represented by a surrogate species: the Risso's dolphin (Section 2.2.1.2.3). The closest relatives to the pygmy killer whale for which diving behavior have been studied are three members of the subfamily Globicephalinae: the short-finned pilot whale, the long-finned pilot whale, and the Risso's dolphin (LeDuc et al. 1999). The pygmy killer whale (at 2.3 m long) is closer in size to the Risso's dolphin (4 m) than to the pilot whales (6 m). Both pygmy killer whales and Risso's dolphins are found in deep water and feed on squid and other cephalopods. The depth distribution for the pygmy killer whale can be found in Table 8.

2.2.1.2.2 *Globicephala macrorhynchus*, Short-finned Pilot Whale

Short-finned pilot whales occur in tropical and warm-temperate waters along the continental shelf and slope (Davis et al. 1998). Short-finned pilot whales feed pre-dominantly on squid, but they also feed on octopus and fish occasionally (Mintzer et al. 2008; Reeves et al. 2002). On the U.S. Pacific coast the neritic cephalopod, *Loligo* spp., is the dominant prey (Mintzer et al. 2008). Short-finned pilot whales feed on vertically migrating prey, diving deep during dusk and dawn and staying near surface at night (Baird et al. 2003).

In order to build a representative depth distribution for short-finned pilot whales, data from Figure 9 in Wells et al. (2013) were used. Wells et al. (2013) tagged two male pilot whales after a mass stranding event in the Florida Keys. However, one of the individual tags stopped transmitting after 16 days, but the other tag transmitted for a total of 67 days; thus, the representative depth distribution contains only the Wells et al.

(2013) data from the individual with the longer transmission time. Due to the lack of data on time spent at depth, the proportion of dives made to specific depth ranges from Wells et al. (2013) will be used as a proxy for percentage of time spent at depth. The depth distribution for short-finned pilot whales is given in Table 7.

Table 7. Percentage of Time at Depth for the Short-Finned Pilot Whale[1,2]

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

[1]Based on data from Wells et al. (2013)
[2]This depth distribution is also representative of the following species: Fraser's dolphin, pygmy sperm whale, and dwarf sperm whale

Aguilar Soto et al. (2008) reported a maximum dive depth of 1019 m for 23 whales near the Canary Islands, which is similar to the deepest depth bin in Table 7. While the maximum depth in Jensen et al. (2011) (roughly 700 m) is hundreds of meters shallower than in the distribution above, the total time spent deeper than this depth constitutes a very small percentage of the whale's total time.

2.2.1.2.3 *Grampus griseus*, Risso's Dolphin

Risso's dolphins are commonly found in temperate and tropical waters along continental slopes (Azzellino et al. 2008; Baumgartner 1997; Green et al. 1992). Although little is known about their foraging or diving behavior, vertically migrating cephalopods are presumed to be the primary food source for Risso's dolphins (Clarke and Pascoe 1985).

In order to build a representative depth distribution, data from Figure 5 in Wells et al. (2009) were used. Wells et al. (2009) reported on the movement and diving behavior of a rehabilitated adult male Risso's dolphin that stranded on the Gulf coast of Florida. Based on Figure 5, the depth distribution for Risso's dolphins was estimated for four 6-hour blocks of time. The tagged animal in this study travelled through waters with a mean depth of 548 m (range 3–2300 m), and was therefore likely not diving close to the seafloor. The deepest dive recorded on the tag was in the 400–500 m depth range, and less than 0.1 percent of dives were deeper than 200 m (Wells et al. 2009). The average time spent in these depth bins was calculated for the representative depth distribution. The depth distribution for the Risso's dolphin is given in Table 8.

Table 8. Percentage of Time at Depth for the Risso's Dolphin[1,2]

Depth Bin (m)	% of Time at Depth
0–1	24.8
1–2	13.5
2–10	16.5
10–50	43.5
50–100	1.2
100–150	0.1
150–600	0.4

[1]Based on data from Wells et al. (2009)
[2]This depth distribution is also representative of the following species: the pygmy killer whale, melon-headed whale, and false killer whale

2.2.1.2.4 *Lagenodelphis hosei*, Fraser's Dolphin

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

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

Due to the lack of available data on the diving behavior of the Fraser's dolphin, it will be represented by a surrogate species: the short-finned pilot whale (Section 2.2.1.2.2). Dolar et al. (1999) found that Fraser's dolphins have myoglobin concentrations consistent with those of other deep-diving marine mammals, and relative muscle masses much greater than those of other dolphins their size, both of which are indicative of enhanced diving ability. Therefore, despite their smaller size, the Fraser's dolphin will be modeled as a short-finned pilot whale, another species in the family Delphinidae which feeds on mesopelagic and bathypelagic prey at similar deep depths (Desportes and Mouritsen 1993; Gannon et al. 1997). The depth distribution for the Fraser's dolphin is given in Table 7.

2.2.1.2.5 *Orcinus orca*, Killer Whale

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

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 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 in Table 9. 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 killer whales is given in Table 9. 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 9.

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

Depth Bin (m)	% of Time at Depth
0–20	81.51
20–40	8.60
40–60	4.45
60–80	2.37
80–100	2.12
100–120	0.53
120–140	0.32
140–150	0.18

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

In order to build a representative depth distribution for mammal-eating killer whales (Table 10), 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 Figures 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) were 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).

Table 10. Percentage of Time at Depth for Mammal-Eating Killer Whales[1]

Depth Bin (m)	% of Time at Depth	Depth Bin (m)	% of Time at Depth
0–10	42.91	50–60	2.46
10–20	23.32	60–70	1.66
20–30	13.94	70–80	0.82
30–40	8.27	80–100	0.36
40–50	5.97		

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

In the absence of ecotype information for the killer whales found in the region, the depth distribution in Table 10 will be used to represent killer whales in the MITT Study Area.

2.2.1.2.6 *Peponocephala electra*, Melon-headed Whale

Melon-headed whales occur in oceanic tropical and subtropical waters (Perryman et al. 1994). Melon-headed whales feed on a variety of mesopelagic fish (e.g., myctophids) and cephalopod species (Brownell Jr. et al. 2009; Gross et al. 2009; Jefferson and Barros 1997).

No data have been collected on the dive behavior of the melon-headed whale, although some inferences can be made from the primary prey species. Myctophids are vertical migrators that descend to depths of 700–3,000 m during the day and rise to 200 m or less at night (Clarke 1973), when melon-headed whales are thought to feed (Brownell Jr. et al. 2009). Cephalopods are also vertical migrators, descending to depths of 400–700 m during the day and rising to 100–150 m at night (Young 1978).

Due to the lack of available data on the diving behavior of the melon-headed whale, it will be represented by a surrogate species: the Risso's dolphin (Section 2.2.1.2.3). Both species are members of the same subfamily, Globicephalinae, feed on mesopelagic prey, and are similar in size. The closest relative to the melon-headed whale is actually the pilot whale; however, pilot whales are more than twice the size of melon-headed whales (LeDuc et al. 1999). The small size of melon-headed whales may indicate that they do not dive as deeply as their larger relatives; thus, the Risso's dolphin is a more suitable surrogate species for dive behavior. The depth distribution for the melon-headed whale is given in Table 8.

2.2.1.2.7 *Pseudorca crassidens*, False Killer Whale

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

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

Due to the lack of available data on the diving behavior of the false killer whale, it will be represented by a surrogate species: the Risso's dolphin (Section 2.2.1.2.3). The closest relatives to the false killer whale for which diving behavior have been studied are three members of the subfamily Globicephalinae: the short-finned pilot whale, the long-finned pilot whale, and the Risso's dolphin (LeDuc et al. 1999). False killer whales are in between these species in size, but the limited data suggest that false killer whales do not dive as deep as pilot whales. Risso's dolphins and false killer whales also both feed on pelagic cephalopods (Clarke and Pascoe 1985). The depth distribution for the false killer whale is given in Table 8.

2.2.1.2.8 *Stenella attenuata,* Pantropical Spotted Dolphin

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

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. Baird reported maximum daytime and nighttime dive depths at 122 m and 213 m, respectively (Baird et al. 2001); however, Scott and Chivers (2009) calculated that dives to more than 120 m accounted for less than 0.1 percent of all dives. They also noted that daytime dives were primarily shallow and above the thermocline (Scott and Chivers 2009). The depth distribution for pantropical spotted dolphins is given in Table 11.

Table 11. Percentage of Time at Depth for the Pantropical Spotted Dolphin[1,2]

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

Depth Bin (m)	% of Time at Depth
70–80	0.6
80–90	0.6
90–100	0.4
100–110	0.4
110–120	0.3
120–130	0.1
130–140	0.1
140–150	0.1
150–160	0.1
160–170	0.1

[1]Based on data from Baird et al. (2001) and Scott and Chivers (2009)
[2]This depth distribution is also representative of the following species:
striped dolphin and spinner dolphin

Stenella coeruleoalba, Striped Dolphin

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

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

Due to the lack of available data on the diving behavior of the striped dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.8). The observed pattern of shallow daytime shallow diving and deeper nighttime diving reported in Minamikawa et al. (2003) is consistent with similar diving behavior seen in pantropical spotted dolphins which are also in the genus *Stenella*. Additionally, all three species occur in similar water depths (Davis et al. 1998). However, it is acknowledged that the striped dolphin may dive to deeper depths on average, due to the deep maximum dive depth recorded by Minamikawa et al. (2003). The depth distribution for striped dolphins is given in Table 11.

2.2.1.2.10 *Stenella longirostris*, Spinner Dolphin

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

No data have been collected on the dive behavior of the spinner dolphin. Many of the vertically migrating prey of the spinner dolphin spend daytime hours at depths from 700–3,000 m, but ascend to depths between the surface and 200 m at night. Spinner dolphins in Hawaiian waters mostly forage in deep water at dusk and early evening, but dive to shallow depths due to the vertical migration of their prey at night (Benoit-Bird and Au 2003; Lammers 2004).

Due to the lack of available data on the diving behavior of the spinner dolphin, it will be represented by a surrogate species: the pantropical spotted dolphin (Section 2.2.1.2.8). Pantropical spotted dolphins also forage mostly at night on vertically migrating fish and cephalopod prey and their foraging dives are primarily limited to the upper 200 m of the water column (Baird et al. 2001). Gross et al. (2009) found no niche differentiation between the two species. The depth distribution for striped dolphins can be found in Table 11.

2.2.1.2.11 *Steno bredanensis*, Rough-toothed Dolphin

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

In order to build a representative depth distribution for rough-toothed dolphins, data from Table 9 in Wells et al. (2008) were used. Wells et al. (2008) reported time-at-depth data from four rehabilitated and released adult rough-toothed dolphins in the Atlantic Ocean and presented the percentage of dives to greater than 2 m for each animal. While these data underestimate surface time (since an animal had to dive below 2 m depth for the tag to save the data), they indicate that rough-toothed dolphins spend the majority of their time in the upper 25 m of the water column. Only two of the four dolphins (three dives total) reached the 200–300 m depth bin, and dives were generally shallowest during the daytime. The data from Wells et al. (2008) were averaged across all four animals. The depth distribution for rough-toothed dolphins is given in Table 12.

Table 12. Percentage of Time at Depth for the Rough-Toothed Dolphin[1]

Depth bin (m)	% of Time at Depth
0–10	78.0
10–25	16.2
25–50	3.8
50–75	0.9
75–100	0.3
100–150	0.1
150–200	0.01
200–300	0.01

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

Other than the Wells et al. (2008) study, little data have been collected on the dive behavior of the rough-toothed dolphin. An early study by Watkins et al. (1987) reported rough-toothed dolphins rubbing against a deployed hydrophone at a depth of 70 m.

2.2.1.2.12 *Tursiops truncatus*, Bottlenose Dolphin

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

Little data have been collected on the dive behavior of bottlenose dolphins. In order to build a representative depth distribution for bottlenose dolphins, data from Table 4 in Klatsky (2004) were used. Dolphins 39999 and 40000 were tagged for 30 and 48 hours, respectively, whereas Dolphin 40001 was tracked for 45 days, providing 792 hours of dive data. So, while Klatsky (2004) presents the percentage of time at depth for three individuals, only the data from Tag 40001 were considered for the depth distribution in order to provide the most comprehensive view of bottlenose dolphin diving behavior. Klatsky (2004) reported that the maximum recorded depth of a dolphin was 492 m, therefore, that depth was used as the maximum depth associated with this distribution. The depth distribution for bottlenose dolphins is given in Table 13.

Table 13. Percentage of Time at Depth for the Bottlenose Dolphin[1]

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

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

These data are consistent with animals foraging up to 500 m off Hawaii, and spending the majority of their time between the surface and 50 m (Baird et al. 2014).

2.2.1.3 Family Kogiidae

2.2.1.3.1 *Kogia breviceps,* Pygmy Sperm Whale

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

Little data have been collected on the dive behavior of pygmy sperm whales. Sightings of pygmy sperm whales in the North Atlantic are most common in waters ranging from 400 to 1,000 m in depth (Clarke 2003; Scott et al. 2001; Waring et al. 2006). Based on the analysis of the stomach contents of whales stranded in New Zealand, Beatson (2007) concluded that pygmy sperm whales feed at shallower depths within the water column than sperm whales, although some prey species are found at depths greater than 600 m. Plön (2004) found that prey species from the stomachs of stranded pygmy sperm whales in South Africa are found at depths below 300 m.

Due to the lack of available data on the diving behavior of the pygmy sperm whale, it will be represented by a surrogate species: the short-finned pilot whale (Section 2.2.1.2.2). The short-finned pilot whale is another primarily squid-eating species (Mintzer et al. 2008; Reeves et al. 2002) which forages deep in the water column (Jensen et al. 2011). The broad similarity in prey types and oceanic habitat suggests similarity in diving behavior to the short-finned pilot whale. The depth distribution for the pygmy sperm whale can be found in Table 7.

2.2.1.3.2 *Kogia sima,* Dwarf Sperm Whale

Dwarf sperm whales have a cosmopolitan distribution in all temperate and tropical waters (Willis and Baird 1998). Little data have been collected on the dive behavior of dwarf sperm whales. There is some indication that dwarf sperm whales have a more coastal distribution than pygmy sperm whales, and prey often include more continental shelf and slope species than those of the pygmy sperm whale (Ross 1979; Wang et al. 2002). The preferred prey species of dwarf sperm whales are found deep in the water column, with some species found below 400 m (Wang et al. 2002).

Due to lack of available data on the diving behavior of the dwarf sperm whale, it will be represented by a surrogate species: the short-finned pilot whale (Section 2.2.1.2.2). The broad similarity in depth at which preferred prey can be found and oceanic habitat suggests similarity in diving behavior to the short-finned pilot whale. In addition, the dwarf sperm whale’s closest relative, the pygmy sperm whale, is also represented by the short-finned pilot whale. The depth distribution for the dwarf sperm whale can be found in Table 7.

2.2.1.4 Family Physeteridae

2.2.1.4.1 *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° 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, a separate depth distribution was generated for the Pacific Ocean. In general, time spent at depth in different 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 the 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	30.24
51–100	4.77
101–150	3.29
151–200	3.30
201–250	3.13
251–300	2.55
301–350	2.60
351–400	3.60
401–450	5.31
451–500	6.48
501–600	9.76
601–700	6.46
701–800	8.58
801–900	8.38
901–1000	1.26
1001–1100	0.34

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

2.2.1.5 Family Ziphiidae

2.2.1.5.1 *Indopacetus pacificus*, Longman's Beaked Whale

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

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

Due to the lack of available data on the diving behavior of the Longman's beaked whale, it will be represented by a surrogate species: the Blainville's beaked whale (Section 2.2.1.5.2). Though originally placed in the *Mesoplodon* genus along with the Blainville's beaked whale, differences in features of the skull have led to the reclassification of this species into its own genus, *Indopacetus*. This taxonomic is the primary reason for using Blainville's beaked whale as the surrogate species. The depth distribution for the Blainville's beaked whale can be found in Table.

2.2.1.5.2 *Mesoplodon densirostris*, Blainville's Beaked Whale

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

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 (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 Blainville's beaked whales is given in Table 15.

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

Depth Bin (m)	% of Time at Depth
1–100	54.3
100–200	10.2
200–300	3.8
300–400	3.2
400–500	3.7
500–600	3.4
600–700	3.8
700–800	4.2
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 (2008a, 2008b), Tyack et al. (2006), and Tyack (2010)

[2] This depth distribution is also representative of the Longman's beaked whale and the ginkgo-toothed beaked whale

2.2.1.5.3 *Mesoplodon ginkgodens*, Ginkgo-toothed Beaked Whale

Ginkgo-toothed beaked whales are known from less than 30 strandings and have not yet been seen in the wild (MacLeod et al. 2006). The species is believed to inhabit tropical and temperate waters of the Indo-Pacific Ocean (Jefferson et al. 2015). The closest confirmed specimen to the MITT Study Area was a likely dependent calf, that was reported caught among squid-baited longlines near Phonpei in the Federated States of Micronesia, suggesting it's mother may have been attempting to depredate the squid or the intended catch (Dalebout et al. 2008).

Due to the lack of available data on the diving behavior of the ginkgo-toothed beaked whale, it will be represented by a surrogate species: the Blainville's beaked whale (Section 2.2.1.5.2). Ginkgo-toothed beaked whales are estimated to be similar in size to Blainville's beaked whales (Trites and Pauly 1998). Ginkgo-toothed beaked whales are also thought to produce frequency-modulated echolocation clicks characteristic of other *Mesoplodon* species (Baumann-Pickering et al. 2014)., although they may be unique in their genus in exhibiting primarily nocturnal foraging behavior (Baumann-Pickering et al. 2014). The depth distribution for the ginkgo-toothed beaked whale's surrogate, the Blainville's beaked whale can be found in Table 15.

2.2.1.5.4 *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 contents 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 from Figure 1 from Aguilar de Soto et al. (2006), Figures 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 (2008a, 2008b), Figure 1a from Kvadsheim et al. (2012), and Figures 2a and 3a from Schorr et al. (2014) were considered. 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 in Barlow et al. (2013) is a typical dive profile for a tagged whale captured over a 15 hour period. Raw DTAG data collected on multiple occasions for an animal in Liguria, Italy, provided by Johnson and Sturlese (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 typical depth distribution calculated. 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 the Cuvier's Beaked Whale[1]

Depth Bin (m)	% of Time at Depth
0–100	31.9
100–200	10.3
200–300	11.7
300–400	5.5
400–500	4.1
500–600	3.9
600–700	5.1
700–800	4.1
800–900	3.4
900–1,000	4.8
1,000–1,100	4.3
1,100–1,200	3.3
1,200–1,300	2.2
1,300–1,400	1.4
1,400–1,500	1.1
1,500–1,600	0.3
1,600–1,700	0.9
1,700–1,800	0.5
1,800–1,900	0.8

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

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.

2.2.2 Sea Turtles

2.2.2.1 Family Dermochelyidae

2.2.2.1.1 *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° S (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 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 (Table 17). These findings support the hypothesis that deep dives are periodically employed to survey the water column for diurnally descending gelatinous prey.

Table 17. 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	0.008
1,000–1,100	0.004
1,100–1,200	0
1,200–1,280	0.008

[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. (2014) found that over 90% of the time was spent in the top 100 m of the water column, and 25% of time was spent at the surface. 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 (Dodge et al. 2014; 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).

2.2.2.2 Family Cheloniidae

2.2.2.2.1 *Caretta caretta,* Loggerhead Sea Turtle

Loggerhead turtles are widely distributed in subtropical and temperate waters (Dodd Jr. 1988). The loggerhead turtle occurs worldwide in habitats ranging from coastal estuaries to waters far beyond the continental shelf (Dodd Jr. 1988). The species may be found hundreds of miles out to sea, as well as in inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers. Results from tagging data of juvenile loggerheads in both the eastern and western North Atlantic suggest that the location of currents and associated frontal eddies are important to the foraging ecology of the pelagic stage of this species (McClellan et al. 2007). Tagging data revealed that migratory routes may be coastal or may involve crossing deep ocean waters; an oceanic route may be taken even when a coastal route is an option (Schroeder et al. 2003). Their large heads support powerful jaws and enable them to feed on hard-shelled prey, such as whelks and conch (Erhart et al. 2003).

In order to build a representative depth distribution for loggerhead turtles in the MITT Study Area, data from Figure 2c in Howell et al. (2010) and the text of Sakamoto et al. (1990) were used. The data recorded in Howell et al. (2010) are an average of data from fourteen adult loggerheads captured incidentally by long-line vessels in the central North Pacific Ocean during 2002–2004. The turtles were tracked for a period ranging from 51-to-578 days. Technical limitations of the tags used in the Howell et al. 2010) study did not allow for the precise dive depth to be recorded at depths greater than 150 m. The maximum dive depth in other literature for the loggerhead turtle is 233 m, recorded from an female turtle tagged off the coast of Japan (Sakamoto et al. 1990). This value was used to represent the maximum depth for the representative depth distribution below. The depth distribution for loggerhead sea turtles is given in Table 18.

Table 18. Percentage of Time at Depth for the Loggerhead Turtle[1]

Depth (m)	% of Time at Depth	Depth (m)	% of Time at Depth
0–1	19.25	31–40	0.25
2 –5	43.75	41–50	0.25
6–10	13.00	51–60	0.25
11–15	9.00	61–80	0.25
16–20	9.00	81–100	0.25
21–25	3.00	101–150	0.25
26–30	1.25	150 – 233	0.25

[1]Based on Howell et al. (2010) and Sakamoto et al. (1990)

While other studies did not include usable depth distributions for loggerhead turtles, they did provide additional information to categorize dive behavior. Most studies found that, on average, loggerhead turtles spend over 90 percent of their time underwater (Byles 1988; Narazaki et al. 2006; Renaud and Carpenter 1994) and remain at depths shallower than 100 m (Hawkes et al. 2006; Houghton et al. 2002; McClellan et al. 2007; Narazaki et al. 2006; Polovina et al. 2003). Routine dive depths are typically shallower than 30 m (Hochscheid et al. 2010; Houghton et al. 2002), although dives of up to 233 m were recorded for a post-nesting female loggerhead off Japan (Sakamoto et al. 1990), and time-depth recorder (TDR)-tagged turtles near Brazil recorded occasional dives in the 200–300 m depth bin (Barcelo et al. 2013). Dives can last anywhere from 4-to-120 minutes (Bentivegna et al. 2003; Byles 1988; Dodd and Byles 2003; Renaud and Carpenter 1994; Sakamoto et al. 1990), though approximately 80 percent have a duration of about 2 minutes (Howell et al. 2010).

2.2.2.2.2 *Chelonia mydas,* Green Sea Turtle

The green turtle has a global distribution, occurring throughout tropical and, to a lesser extent, subtropical waters (Marine Turtle Specialist Group 2004) and is generally distributed between 30° N and 30° S. Green turtles are highly migratory and undertake complex movements and migrations through geographically disparate habitats, with the longest migrations occurring between foraging habitats and nesting beaches. Hatchlings swim to offshore areas where they float passively in major current systems. Juveniles leave the pelagic habitat and recruit to protected lagoons and open coastal areas that are rich in seagrass or marine algae (Bresette et al. 2006), the main prey items of green turtles. Green turtles will spend the majority of their lives in these coastal areas (Bjorndal and Bolten 1988; NMFS and USFWS 1991). A small number of green turtles appear to remain in open ocean habitats for extended periods, perhaps never recruiting to coastal foraging sites (NMFS and USFWS 2007a; Pelletier et al. 2003). The optimal developmental habitats for late juveniles and foraging habitats for adults are warm, shallow waters (3–5 m in bottom depth) with abundant submerged aquatic vegetation and in close proximity to nearshore reefs or rocky areas (Ernst et al. 1994).

In order to build a representative depth distribution for green sea turtles, data from Figures 2 and 4 from Godley et al. (2002) and a maximum dive depth from Rice and Balazs (2008) were used. Technical limitations of the tag used in the Godley et al. (2002) study did not allow for the precise dive depth to be recorded at depths greater than 45 m. The maximum dive depth in other literature for the green turtle is 138 m, recorded from an adult female turtle migrating between nesting grounds on French Frigate Shoals in the Northwest Hawaiian Islands and foraging grounds off Laniakea, Oahu, HI (Rice and Balazs 2008). This value was used to represent the maximum depth for the dive distribution profile. The percentage of time that green turtles spent in each behavioral state (e.g., traveling versus foraging) was not reported in the literature used for the development of the depth distribution. As a result, the time spent in each behavioral state was assumed to be equal and was averaged for a composite dive depth distribution. The depth distribution for green sea turtles is given in Table 19.

Table 19. Percentage of Time at Depth for the Green Turtle[1]

Depth Bin (m)	% of Time at Depth
0–5	59.23
6–10	16.98
11–15	11.68
16–20	6.78
21–25	2.61
26–30	1.39
31–35	0.73
36–40	0.26
41–45	0.06
45–138	0.28

[1]Based on data from Godley et al. (2002) and Rice and Balzacs (2008)

While other studies did not include usable depth distributions for green turtles, they did provide additional information to categorize dive behavior. Blanco et al. (2012) reported that four turtles near Costa Rica spent 46% of their time at the surface, and while the majority of their time was in the top 10 m, the deepest dive was to 110 m. Seventy percent of the dives of migrating and foraging turtles near Brazil were to less than 30 m depth (Chambault et al. 2015). Hatase (2006) observed that green turtles dive to a maximum of 80 m in areas of the open ocean, where depths are greater than 200 m, while green turtles migrating between the northwestern and main Hawaiian Islands reached a maximum depth greater than 138 m at night (the deepest dives ever recorded for a green turtle), but only 4 m during the day (Rice and Balazs 2008). In their coastal habitat, green turtles typically make dives shallower than 30 m (Cheng et al. 2013; Godley et al. 2002; Hatase et al. 2006; Hays et al. 2000; Hochscheid et al. 1999) and often not exceeding 17.5 m (Ballorain et al. 2013; Hays et al. 2004; Rice and Balazs 2008). Green turtles are known to both forage and rest at depths of 20–50 m (Balazs 1980; Brill et al. 1995).

2.2.2.2.3 *Eretmochelys imbricata*, Hawksbill Sea Turtle

The hawksbill is the most tropical of the world's sea turtles, occurring in all oceans but rarely above or below 30° N and 30° S (Witzell 1983). Hawksbill nesting occurs in at least 70 countries, although much of it now at only low densities. Juveniles and adults share the same foraging areas, including tropical, nearshore waters associated with coral reefs, hard bottoms, or estuaries with mangroves (Musick and Limpus 1997). Coral reefs are optimal hawksbill habitat for juveniles, subadults, and adults (NMFS and USFWS 1998). Hawksbills are also found around rocky outcrops and high-energy shoals—optimum sites for sponge growth, their preferred prey item—as well as mangrove-fringed bays and estuaries where coral reefs are absent (NMFS and USFWS 2007b). While hawksbills are known to occasionally migrate large distances, possibly in the open ocean, this is the most coastal of all marine turtles. There is very little available information on hawksbills in the pelagic environments of the Atlantic and Pacific Oceans.

In order to build a representative depth distribution for hawksbill sea turtles, data from Figure 6 in van Dam and Diez (1996) and Figure 7 in Blumenthal et al. (2009) were used. Van Dam and Diez (1996) collected data from four immature hawksbills on the foraging and resting dive behavior for resident juvenile hawksbill turtles of Mona Island, Puerto Rico. Van Dam and Diez (1996) reported foraging dives at the study site in Puerto Rico ranging from 19-to-26 min at depths of 8–10 m. Foraging dives of immature hawksbills are shorter in length, ranging from 8.6-to-14 min in duration (van Dam and Diez 1996), with a mean and maximum depth of 5 m and 20 m, respectively (Blumenthal et al. 2009; Lutcavage and Lutz 1997; van Dam and Diez 1996). A maximum dive duration of 73.5 min has been reported for a female hawksbill in the U.S. Virgin Islands (van Dam and Diez 1996). The data recorded in Blumenthal et al. (2009) represent an average of data from eighteen immature hawksbills captured in Blood Bay, Cayman Islands in 2005. Blumenthal et al. (2009) collected time and depth data that recorded for 8 days for each turtle, but the individuals' general movements were tracked for an average of 37 ± 69 days (range 11–316 days). Both datasets used to derive the depth distribution for hawksbill turtles were from juvenile turtles. Ideally, data from adult specimens are preferred since dive capacity and habitat use are influenced by body size (Schreer and Kovacs 1997). However, individuals of the same species in the same habitat can vary in body length by a factor of four (Diez and van Dam 2002; McGowan et al. 2008) and in body weight by a factor of 20 (Storch et al. 2005). To date, there have been no studies where a large number of time depth recorders have been deployed on turtles across a wide range of body sizes, enabling investigation of scaling in dive capacity and habitat use (Blumenthal et al. 2009). As a result, the data obtained from studies with juvenile turtles represents the best available data and should be interpreted as generally representative across the entire hawksbill population. The depth distribution for hawksbill sea turtles is given in Table 20.

Table 20. Percentage of Time at Depth for the Hawksbill Turtle[1]

Depth Bin (m)	% of Time at Depth
0–2	11.31
3–10	66.25
11–20	11.49
21–30	4.68
31–40	3.59
41–50	2.04
51–91	0.65

[1]Based on data from Van Dam and Diez (1996) and Blumenthal et al. (2009)

While other studies did not include usable depth distributions for hawksbill turtles, they did provide additional information to categorize dive behavior. In general, studies have found that hawksbills may have one of the longest routine dive times of all sea turtles. Starbird et al.(1999) reported that internesting females at Buck Island, U.S. Virgin Islands, averaged 56.1 min dives, longer than those reported in Puerto Rico by van Dam and Diez (1996). Turtles in Eastern Tropical Pacific spent 89% of their time in waters less than 10 m deep, with the majority of time in the 5–10 m depth bin, and dove to a maximum depth of 40 m (Gaos et al. 2012). Changes in water temperature have an effect on the behavioral ecology of hawksbill turtles, with an increase in nocturnal dive duration with decreasing water temperatures during the winter (Storch et al. 2005).

2.3 Conclusions

The recommended static depth distributions are provided for 30 marine animal species occurring within the MITT 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

3.1 Introduction

Many marine mammals are known to travel and feed in groups. The 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. Within the MITT Study Area, group size data were collected through a comprehensive and systematic review of available visual survey data and relevant literature. Journal articles, books, technical reports, cruise reports, funding agency reports, theses, dissertations, and raw data from individual researchers, theses, and dissertations were assessed for this report.

Group size data for the MITT Study Area includes mean group size and standard deviation (SD), The SDs are incorporated in NAEMO by randomly and repetitively selecting a value from the Poisson or lognormal distribution defined by the mean group size and SD provided.

3.2 Mariana Islands Training and Testing Study Area Group Sizes

Data from all relevant sources were pooled based on individual species occurring within the MITT Study Area (Table 21). In some instances where data were lacking, data from multiple areas were combined or the geographically closest data were applied. For species not listed here, a group size of 1 is used.

Table 21. Mean Group Size and Standard Deviation (SD) for Cetaceans in the Mariana Islands Training and Testing Study Area

Common name	Species name	Mean	SD	References
Minke whale	*Balaenoptera acutorostrata*	1.00		Norris et al. 2017
Sei whale	*Balaenoptera borealis*	1.15	0.21	Oleson and Hill 2011; Fulling et al. 2011
Brydes whale	*Balaenoptera edeni*	1.13	0.23	Oleson and Hill 2011; Fulling et al. 2011; Mobley Jr 2007
Blue whale	*Balaenoptera musculus*	2.80		Bradford et al. 2017
Omuras whale	*Balaenoptera omurai*	1.13	0.23	Oleson and Hill 2011; Fulling et al. 2011; Mobley Jr 2007
Fin whale	*Balaenoptera physalus*	2.00		Bradford et al. 2017
Pygmy killer whale	*Feresa attenuata*	6.67	1.15	Fulling et al. 2011; Hill et al. 2011; Hill et al. 2013c

Table 21. Mean Group Size and Standard Deviation (SD) for cetaceans in the Mariana Islands Training and Testing Study Area (Cont'd)

Common name	Species name	Mean	SD	References
Short-finned pilot whale	*Globicephala macrorhynchus*	25.64	9.47	Hill et al. 2011; Hill et al. 2013a; Hill et al. 2013b; Hill et al. 2017; Hill et al. 2016; Oleson and Hill 2011; Fulling et al. 2011; Ligon et al. 2011
Risso's dolphin	*Grampus griseus*	14.80	16.69	Bradford et al. 2017; Oleson and Hill 2011
Longmans beaked whale	*Indopacetus pacificus*	59.80		Bradford et al. 2017
Pygmy sperm whale	*Kogia breviceps*	3.00		Mobley Jr 2007
Dwarf sperm whale	*Kogia sima*	2.50	1.32	Hill et al. 2013a; Hill et al. 2017; Mobley Jr 2007
Fraser's dolphin	*Lagenodelphis hosei*	283.30		Bradford et al. 2017
Humpback whale	*Megaptera novaeangliae*	4.33	3.21	Eldredge 2003; Fulling et al. 2011; Hill et al. 2017
Blainvilles beaked whale	*Mesoplodon densirostris*	1.88	0.85	Hill et al. 2013c; Hill et al. 2017; Hill et al. 2016; Oleson and Hill 2011
Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	1.88	0.85	Hill et al. 2013c; Hill et al. 2017; Hill et al. 2016; Oleson and Hill 2011
Killer whale	*Orcinus orca*	4.35	0.49	Bradford et al. 2017; Eldredge 2003
Melon-headed whale	*Peponocephala electra*	73.25	30.05	Fulling et al. 2011; Oleson and Hill 2011
Sperm whale	*Physeter macrocephalus*	7.32	1.44	Fulling et al. 2011; Hill et al. 2013c; Hill et al. 2017; Oleson and Hill 2011
False killer whale	*Pseudorca crassidens*	10.20	3.41	Fulling et al. 2011; Hill et al. 2013c; Hill et al. 2016; Oleson and Hill 2011
Pantropical spotted dolphin	*Stenella attenuata*	30.74	15.15	Fulling et al. 2011; Hill et al. 2013a; Hill et al. 2013c; Hill et al. 2017; Hill et al. 2016; Ligon et al. 2011; Mobley Jr 2007; Oleson and Hill 2011

Table 21. Mean Group Size and Standard Deviation (SD) for cetaceans in the Mariana Islands Training and Testing Study Area (Cont'd)

Common name	Species name	Mean	SD	References
Spinner dolphin	*Stenella longirostris*	36.53	24.47	Fulling et al. 2011; Hill et al. 2013a; Hill et al. 2013b; Hill et al. 2013c; Hill et al. 2017; Hill et al. 2016; Ligon et al. 2011; Oleson and Hill 2011
Rough-toothed dolphin	*Steno bredanensis*	5.75	3.59	Fulling et al. 2011; Hill et al. 2013c; Hill et al. 2017; Mobley Jr 2007
Striped dolphin	Striped dolphin	18.20	13.01	Fulling et al. 2011; Oleson and Hill 2011
Bottlenose dolphin	*Tursiops truncatus*	5.81	2.84	Fulling et al. 2011; Hill et al. 2013a; Hill et al. 2013b; Hill et al. 2013c; Hill et al. 2017; Hill et al. 2016
Cuviers beaked whale	*Ziphius cavirostris*	2.50	2.12	Hill et al. 2016; Mobley Jr 2007

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