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Dive Distribution and Group Size Parameters for Marine Species Occurring in Navy Training and Testing Areas in the North Atlantic and North Pacific Oceans

Stephanie L. Watwood
NUWC Division Newport

Danielle M. Buonantony
Naval Facilities Engineering Command, Atlantic

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Naval Undersea Warfare Center Division Newport, Rhode Island

PREFACE

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EXECUTIVE SUMMARY

One important element of Phase II environmental planning is the acoustic effects analysis executed with the Navy Acoustic Exposure Model (NAEMO) software. NAEMO was developed to explore possible exposure 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 Atlantic Fleet Training and Testing (AFTT), Hawaii-Southern California Training and Testing (HSTT), Northwest Training and Testing (NWTT), and Mariana Islands Training and Testing (MITT) Study Areas that will be modeled using NAEMO for Phase II analyses. Additionally, group size information is presented for species occurring in the AFTT, HSTT, NWTT, Mediterranean Training and Testing (MED), and Gulf of Alaska (GOA) Study Areas. In total, data are presented for 54 cetacean, 12 pinniped, one mustelid, one sirenian, and six sea turtle species.

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LIST OF ABBREVIATIONS AND ACRONYMS

3MB	Marine Mammal Movement and Behavior
cm	Centimeter
AFTT	Atlantic Fleet Training and Testing
AOR	Areas of responsibility
CETAP	Cetacean and Turtle Assessment Program
d	Day
DoN	Department of the Navy
E AK	Eastern Alaska
FEEZ	Foreign Exclusive Economic Zones

LIST OF ABBREVIATIONS AND ACRONYMS (Cont'd)

GOA	Gulf of Alaska
hr	Hour
HSTT	Hawaii-Southern California Training and Testing
IUCN	International Union for Conservation of Nature and Natural Resources
kg	Kilogram
km	Kilometer
km/hr	Kilometers per hour
m	Meter
min	Minute
m/s	Meters per second
MED	Mediterranean Training and Testing
MITT	Mariana Islands Training and Testing
NAEMO	Naval Acoustic Exposure Model
NWHI	Northwestern Hawaiian Islands
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWTT	Northwest Training and Testing
NUWC	Naval Undersea Warfare Center
SD	Standard deviation
sec or s	Second
TDR	Time depth recorders
USFWS	United States Fish and Wildlife Service
W AK	Western Alaska

DIVE DISTRIBUTION AND GROUP SIZE PARAMETERS FOR MARINE SPECIES OCCURING IN NAVY TRAINING AND TESTING AREAS IN THE NORTH ATLANTIC AND NORTH PACIFIC OCEANS

1. INTRODCUTION

The Navy Acoustic Effects Model (NAEMO) combines inputs on marine species density, depth distribution, and group size distribution with environmental parameters, propagation characteristics, sound source parameters, and typical training or testing scenarios to determine the potential for acoustic or impulsive exposure to marine species in a given training or testing area. Location-specific density and group size information are used to first patchily distribute a given marine species into a simulation area. The depth distribution is then used to place animals in the water column at depths in which they are typically found. An animal is reassigned a new depth every four minutes throughout the simulation by continually consulting the depth distribution for that species. Where available, seasonal or geographic-specific depth and group size information are used.

This report contains collated data from literature reviews on species-specific group size and depth distribution information. Where data from a given species were lacking, surrogate species were chosen as representative based on genetic relatedless or similarities in habitat, foraging behavior, or anatomy. All depth distribution values for modeling activities within the Atlantic Fleet Training and Testing (AFTT), Hawaii-Southern California Training and Testing (HSTT), Northwest Training and Testing (NWTT), and Mariana Islands Training and Testing (MITT) Study Areas are contained herein. Additionally, group size data for AFTT, HSTT, NWTT, Mediterranean Training and Testing (MED), and Gulf of Alaska (GOA) Study Areas are recommended.

2. RECOMMENDATION FOR MODELING 3-DIMENSIONAL DIVING BEHAVIOR OF MARINE MAMMALS FOR USE IN NAVY ACOUSTIC EFFECTS MODEL ANALYSIS

2.1 PURPOSE

NAEMO was developed to explore the possible effects of anthropogenic sound on marine mammals, combining established acoustic propagation modeling with data regarding the distribution and abundance of marine mammal species. This chapter recommends species-typical static depth distributions for all marine mammal species that occur in the AFTT, HSTT, NWTT, and MITT Study Areas that will be modeled using NAEMO for Phase II analyses.

2.2 GENERAL METHODS

2.2.1 Data Collection

2.2.1.1 Literature Review

A comprehensive and systematic review of relevant literature and data was conducted. The following types of information were assessed: journals, books, technical reports, cruise reports, funding agency reports, theses, dissertations, and raw data from individual researchers. Additionally, individual scientists were contacted for assistance in locating movement and diving behavior resources, where appropriate.

2.2.1.2 Data Parameters

For each species, data on specific behavioral parameters were collected during the literature review (table 1). These parameters were selected as useful for quantifying overall diving and movement behavior (Houser, 2006).

2.2.2 Tier Designation

2.2.2.1 Definition

Upon completion of a comprehensive literature review for each species, that species was assigned a Tier designation. The Tier assignment is a useful means to assess the available published data on swimming and diving behavior for a given species. Tiers 1–3 represent decreasing levels of detail in the published literature on movement and diving behavior. Descriptions of each Tier are provided below.

Table 1. Movement Behavior Variables Collected During Literature Review to Determine Tier Assignment

Variable	Definition
Behavior State	Broad behavioral category (foraging, traveling, resting, etc.).
Number of Days Tracked	Number of days where satellite tag was transmitting
Direction (perturbation)	Overall direction of travel
Minimum Distance Traveled (km)	Cumulative straight-line distance between successive fixes
Distance Traveled (km)	Distance covered during observation
Speed (m/s)	Rate of travel in the horizontal plane
Maximum Swim Speed (m/s)	Highest swim speed value recorded
Travel Rate (km/h)	Rate of movement for migrating species on a relatively fixed course
Number of Dives per Hour	Number of separate dives per hour of observation
Percentage of Time Spent Diving	Percentage of total time in dive-surface interval cycles (excludes extended surface intervals)
Dive Duration (min)	Time between when the animal left the surface until it reappeared at the surface
Descent Rate (m/s)	Speed of the animal during the descent phase of a dive
Descent Duration (min)	Duration of the descent phase of a dive
Ascent Rate (m/s)	Speed of the animal during the ascent phase of a dive
Mean Dive Depth (m)	Mean of the deepest depth reached during multiple dives
Maximum Dive Depth (m)	Deepest depth reached during any dive
Percentage of dives deeper than 300 m	Percentage of all dives with a portion of the dive occurring deeper than 300 m
Bottom Depth (m)	Depth of the bottom phase of the dive, between the descent and ascent phases
Bottom Time (min)	Duration of the bottom phase of the dive
Bottom Following?	Yes or No as to whether the animal maintained a constant altitude over the seafloor during the bottom phase of the dive
Maximum Dive Duration (min)	Longest dive duration for all dives
Number of Dives per Day	Number of dives in a 24-hour period
Percentage of the Dive on Bottom	Percentage of the dive spent in the bottom phase
Percentage of Time Submerged	Percentage of all total time that the animal was beneath the surface
Duration of Dive Bouts (min)	Duration of interval including successive dives preceding an extended surface interval
Reversal Count	Number of vertical excursions (wiggles) in the bottom portion of the dive
Probability of Reversals	Probability of reversals occurring in a dive
Dive Reversal Rate	Number of reversals per dive
Time in Reversal (s)	Duration of bottom period that includes reversals
Reversal Descent (m/s)	Speed of the descent portion of a reversal
Reversal Ascent (m/s)	Speed of the ascent portion of a reversal
Surface Interval Mean (min)	Average duration of time spent at the surface between two dives
Behavioral State Transition Probability	Probability of the animal moving from one behavioral state to another
Location of Study	Location where study occurred
Depth limit (m)	Depth limit (minimum and maximum) of occurrence
Percentage of Time at Depth	Overall percentage of time spent in specified depth bins

2.2.2.2 Tier 1

A species is assigned to Tier 1 if sufficient published information exists to reliably create a realistic three-dimensional track of animal movement. If adequate data were collected for the majority of variables in table 1, the species was assigned to Tier 1. For input into NAEMO, however, only static depth distributions are required. To create a static depth distribution, variable data from table 1 were input into the Marine Mammal Movement and Behavior (3MB) simulation software (Houser, 2006). The 3MB software is used to create dynamic movement profiles over user defined bathymetry and durations. In order to generate a static distribution for input into NAEMO, 100 animals of each Tier 1 species were run for a 24-hour simulation in deep water in which the species is typically found (such that the species would not be bottom-limited). The 24-hour time period ensured that most animals would pass through all behavioral states included in the 3MB species profile, and, therefore, cover a range of movement and behavior patterns. The mean of the resulting depth distributions for each animal over the duration of the simulation was then calculated to create a general static depth distribution for input into NAEMO for each species. This is comparable to averaging time at depth determined from satellite-depth recorders for several animals to create a single depth distribution.

2.2.2.3 Tier 2

If insufficient data exist for a Tier 1 designation (recreation of dynamic behavior), the data are examined for descriptions of time spent in various depth bins. If multiple depth distributions are published, either an average distribution is calculated, or separate distributions are reported if they are specific to particular locations, seasons, age classes, or sex classes. Tier 2 designations generally indicate that less detailed information on diving and foraging behavior exist than for a Tier 1 species.

2.2.2.4 Tier 3

Tier 3 represents the lowest quality depth distribution. Tier 3 species are distributed uniformly in the water column down to a maximum depth. The maximum depth is chosen based on data availability of the following (in order of preference): dive depth from a tagging study, depth of occurrence of primary prey species, depth of the water column from typical habitat. To date there have been no Tier 3 designations, as species lacking specific depth distribution data were modeled with a surrogate species (section 2.2.2.5). However, this Tier description is retained for future Tier assignments in other study areas.

2.2.2.5 Surrogate Species

If insufficient data exist for a Tier 1 or Tier 2 designation, a surrogate species for modeling purposes is considered. Assigning a surrogate species is preferred to a Tier 3 designation, due to the unrealistic nature of the Tier 3 uniform depth distribution. A species will generally only be considered a surrogate for modeling the species in question if the two species are closely related (same Genus or Family), feed on similar prey, and have a distribution in similar water types (e.g., continental shelf waters). The exception is the two species of Kogia, 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.

2.3 DEPTH DISTRIBUTION SUMMARY

Tier designations and surrogate species (if required) for all species are given in table 2. Species modeled with a surrogate have an S preceding their Tier number.

Table 2. Tier Designations and Surrogate Species (If Required) for Marine Mammal Species Occurring in the AFTT and HSTT Study Areas

Species Name	Common Name	Tier[a]	Surrogate species
Cetaceans			
Family Balaenidae			
Balaena mysticetus	Bowhead whale	2	None
Eubalaena glacialis	North Atlantic right whale	2	None
Eubalaena japonica	North Pacific right whale	S2	*Eubalaena glacialis*
Family Balaenopteridae			
Balaenoptera acutorostrata	Common minke whale	2	None
Balaenoptera borealis	Sei whale	S2	*Balaenoptera edeni*
Balaenoptera edeni	Bryde's whale	2	None
Balaenoptera musculus	Blue whale	1	None
Balaenoptera omurai	Omura's whale	S2	*Balaenoptera edeni*
Balaenoptera physalus	Fin whale	1	None
Megaptera novaeangliae	Humpback whale	2	None
Family Delphinidae			
Delphinus capensis	Long-beaked common dolphin	S2	*Stenella attenuata*
Delphinus delphis	Short-beaked common dolphin	S2	*Stenella attenuata*
Feresa attenuata	Pygmy killer whale	S2	*Grampus griseus*
Globicephala macrorhynchus	Short-finned pilot whale	S2	*Globicephala melas*
Globicephala melas	Long-finned pilot whale	2	None
Grampus griseus	Risso's dolphin	2	None
Lagenodelphis hosei	Fraser's dolphin	S2	*Globicephala melas*
Lagenorhynchus acutus	Atlantic white-sided dolphin	S2	*Stenella attenuata*
Lagenorhynchus albirostris	White-beaked dolphin	S2	*Stenella attenuata*
Lagenorhynchus obliquidens	Pacific white-sided dolphin	S2	*Stenella attenuata*
Lissodelphis borealis	Northern right whale dolphin	S2	*Stenella attenuata*
Orcinus orca	Killer whale	2	None
Peponocephala electra	Melon-headed whale	S2	*Grampus griseus*
Pseudorca crassidens	False killer whale	S2	*Grampus griseus*
Stenella attenuata	Pantropical spotted dolphin	2	None
Stenella clymene	Clymene dolphin	S2	*Stenella attenuata*
Stenella coeruleoalba	Striped dolphin	S2	*Stenella attenuata*
Stenella frontalis	Atlantic spotted dolphin	2	None
Stenella longirostris	Spinner dolphin	S2	*Stenella attenuata*
Steno bredanensis	Rough-toothed dolphin	2	None
Tursiops truncatus	Common bottlenose dolphin	1	None

Table 2. Tier Designations and Surrogate Species (If Required) for Marine Mammal Species Occurring in the AFTT and HSTT Study Areas (Cont'd)

Species Name	Common Name	Tier[a]	Surrogate species
Family Eschrichtiidae			
Eschrichtius robustus	Gray whale	2	None
Family Kogiidae			
Kogia breviceps	Pygmy sperm whale	S2	*Globicephala melas*
Kogia sima	Dwarf sperm whale	S2	*Globicephala melas*
Family Monodontidae			
Delphinapterus leucas	Beluga whale	2/S2	*Monodon monoceros*
Monodon monoceros	Narwhal	2	None
Family Phocoenidae			
Phocoena phocoena	Harbor porpoise	1	None
Phocoenoides dalli	Dall's porpoise	2	None
Family Physeteridae			
Physeter macrocephalus	Sperm whale	1	None
Family Ziphiidae			
Berardius arnuxii	Arnoux's beaked whale	S1	*Ziphius cavirostris*
Berardius bairdii	Baird's beaked whale	S1	*Ziphius cavirostris*
Hyperoodon ampullatus	Northern bottlenose whale	S1	*Ziphius cavirostris*
Indopacetus pacificus	Longman's beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon bidens	Sowerby's beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon carlhubbsi	Hubb's beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon densirostris	Blainville's beaked whale	1	None
Mesoplodon europaeus	Gervais' beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon ginkgodens	Ginkgo-toothed beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon layardii	Strap-toothed whale	S1	*Mesoplodon densirostris*
Mesoplodon mirus	True's beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon perrini	Perrin's beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon peruvianus	Pygmy beaked whale	S1	*Mesoplodon densirostris*
Mesoplodon stejnegeri	Stejneger's beaked whale	S1	*Mesoplodon densirostris*
Ziphius cavirostris	Cuvier's beaked whale	1	None
Carnivores			
Family Mustelidae			
Enhydra lutris	Sea otter	2	None
Family Otariidae			
Arctocephalus townsendi	Guadalupe fur seal	S2	*Arctocephalus gazella*
Callorhinus ursinus	Northern fur seal	2	None
Eumetopias jubatus	Steller sea lion	2	None
Zalophus californianus	California sea lion	1	None
Family Phocidae			
Cystophora cristata	Hooded seal	2	None
Erignathus barbatus	Bearded seal	2	None
Halichoerus grypus	Gray seal	2	None

Table 2. Tier Designations and Surrogate Species (If Required) for Marine Mammal Species Occurring in the AFTT and HSTT Study Areas (Cont'd)

Species Name	Common Name	Tier[a]	Surrogate species
Family Phocidae (Cont'd)			
Monachus schauinslandi	Hawaiian monk seal	2	None
Mirounga angustirostris	Northern elephant seal	1	None
Pagophilus groenlandicus	Harp seal	2	None
Phoca vitulina	Harbor seal	1	None
Pusa hispida	Ringed seal	2	None
Sirenians			
Family Trichechidae			
Trichechus manatus	West Indian manatee	2	None

[a] Species modeled with a surrogate have an "S" preceding their Tier number

2.4 DIVE BEHAVIOR SUMMARIES

For each species, a depth distribution is presented, along with references that are the source of the data. Depth bins are given in meters (m), and may be non-uniform both within and between species. For certain species (e.g. North Atlantic right whale, humpback whale, sperm whale, harp seal) more than one depth distribution is given due to documented seasonal or geographic differences in diving behavior. Individual species are listed alphabetically by family and scientific name within each mammal order.

2.5 MARINE MAMMAL DIVE DATA

2.5.1 Cetaceans

2.5.1.1 Family Balaenidae

2.5.1.1.1 Balaena mysticetus, Bowhead Whale. The bowhead whale is a Tier 2 species. Bowhead whales are an exclusively Arctic species with a southward seasonal migration limited to subarctic areas at the advancing ice edges in winter. Five bowhead stocks are recognized as geographically distinct, although some tagging and genetic evidence points towards sympatric ranges of the two eastern Canadian stocks (Moore and Reeves, 1993; Heide-Jorgensen et al., 2006; Reilly et al., 2008). While the global population of bowhead whales is increasing, the Spitsbergen and Okhotsk Sea stocks are sufficiently depleted to warrant protection as endangered species (Reilly et al., 2008). Bowhead whales consume a wide variety of zooplankton (at least 60 species), including copepods, euphausids, mysids, amphipods, and isopods, as well as fish. Feeding behaviors range from surface to sub-surface skimming and bottom feeding as evidenced by direct observations of trailing mud clouds and stomach contents analyses (Lowry, 1993; Würsig and Clark, 1993; Lowry et al., 2004). The maximum dive depths recorded for bowhead whales in the Beaufort Sea by satellite depth-duration tags were 352 m in waters up to 1480 m depth (Krutzikowsky and Mate, 2000), and off West Greenland to 221 m (bottom depth unreported; Simon et al. 2009) although percent time spent at these depths represents <1% of dive times. During feeding and traveling behaviors, in light and heavy ice conditions, bowheads of the Beaufort Sea spent the majority of their tagged time near the surface (table 3) (Simon et al., 2009).

Table 3. Percentage of Time at Depth for the Bowhead Whale

Depth Bin (m)	Percent of Time at Depth
0-1	4.5
1-16	60.0
16-96	33.0
96-352	2.5

Typical dive durations range from 1–18 min (Würsig et al., 1984; Krutzikowsky and Mate, 2000; Simon et al., 2009). Maximum dive durations range from 15 min (spring, West Greenland; Simon et al. 2009) to 64 min (fall, Beaufort Sea; Krutzikowsky and Mate, 2000). Simon et al. (2009) describe two types of dive profiles: U-dives and V-dives. In U-dives, bowhead whales were observed feeding mid-column, sustaining the dive at a mean depth of 79 m (standard deviation (SD) = 64; range: 17–127 m) for the bulk of the dive duration with a mean of 15.2 minutes (SD=4.1). V-dives were characterized by the majority of the dive duration spent in descent and ascent with minimal time at maximum depth (V-dive mean depth = 69 m (SD = 37); range: 15–221 m; mean dive duration: 9.0 min (SD = 5.1) Simon et al., 2009).

2.5.1.1.2 Eubalaena glacialis, North Atlantic Right Whale. The North Atlantic right whale is a Tier 2 species. North Atlantic right whales migrate between temperate and sub-polar feeding grounds (in shelf and near shore waters) and sub-tropical breeding grounds (in near shore coastal waters) (Kenney, 2002). Their prey consists entirely of zooplankton, particularly large copepods. Right whales are skim feeders that swim open-mouthed both at the surface and at depth (and occasionally along the bottom) through patches of congregated prey (Mate and Nieukirk 1992; Kenney et al., 2001; Kenney, 2002). Maximum dive depths reported in the literature are 174 m (Baumgartner and Mate, 2003) and 272 m (Mate and Nieukirk, 1992). D. Nowacek and A. McGregor (pers. comm., Duke University) provided depth distribution information for tagged right whales in two locations, the Bay of Fundy (table 4) and the South Atlantic Bight (table 5). Only tags with attachment durations greater than 30 min were included in the analysis. The data from the Bay of Fundy include 36 tag attachments with an average data record of 4.2 hr (range: 0.7–3.9 hr). The Bay of Fundy is a foraging ground for North Atlantic right whales, and therefore animal distributions reflect animals skim feeding at the surface and at depth.

Table 4. Percentage of Time at Depth for the North Atlantic Right Whale on Foraging Grounds

Depth Bin (m)	Percentage of Time at Depth
0-10	32.87
10-20	3.86
20-30	2.68
30-40	1.97
40-50	3.36
50-60	1.73
60-70	1.56
70-80	3.70
80-90	3.77
90-100	4.24
100-110	7.52

Depth Bin (m)	Percentage of Time at Depth
110-120	8.38
120-130	7.75
130-140	6.27
140-150	5.34
150-160	3.13
160-170	1.36
170-180	0.45
180-190	0.03
190-200	0.03
200-210	0.01
210-220	0.01

There were four tag attachments in the South Atlantic Bight, which had an average duration of 5.4 hr (range: 0.5–18.6 hr). The South Atlantic Bight is a breeding ground, and, therefore, it is assumed that little foraging occurs there. The distribution in table 5 will be used for migration periods also. Note that the depth bins in table 4 (10 m) are larger than the depth bins in table 5 (2 m).

Table 5. Percentage of Time at Depth for the North Atlantic Right Whale on Breeding Grounds and During Migration

Depth Bin (m)	Percentage of Time at Depth
0-2	27.45
2-4	11.40
4-6	12.97
6-8	11.42
8-10	7.81
10-12	6.34
12-14	8.01
14-16	14.13
16-18	0.43
18-20	0.04

2.5.1.1.3 Eubalaena japonica, North Pacific Right Whale. The North Pacific right whale is a Tier 2 species that will be represented by a surrogate species, the North Atlantic right whale (section 2.5.1.1.2). Like its sister species, the North Atlantic right whale, the North Pacific right whale preys exclusively on zooplankton, principally copepods; however, the North Pacific right whale appears to feed primarily on various copepod and krill species (Omura et al., 1969; Tynan, 1999; Tynan et al., 2001; Nichol et al., 2002; Coyle et al., 2008; Gregr and Coyle, 2009). Maximum dive depth is estimated at between 200–300 m based on western North Atlantic right whale dive maximums on the continental shelf (200 m) and Southern right whales (300 m); however, sympatric bowhead whales are capable of dives as deep as 400 m (Heide-Jorgensen et al. 2003). Due to the lack of data on diving behavior, the depth distributions in table 6 and table 7 for the North Atlantic right whale will be considered representative for North Pacific right whales.

Table 6. Percentage of Time at Depth for the North Pacific Right Whale on Foraging Grounds, Based on Data from the Surrogate Species, the North Atlantic Right Whale

Depth Bin (m)	Percentage of Time at Depth
0-10	32.87
10-20	3.86
20-30	2.68
30-40	1.97
40-50	3.36
50-60	1.73
60-70	1.56
70-80	3.70
80-90	3.77
90-100	4.24
100-110	7.52
110-120	8.38
120-130	7.75
130-140	6.27
140-150	5.34
150-160	3.13
160-170	1.36
170-180	0.45
180-190	0.03
190-200	0.03
200-210	0.01
210-220	0.01

Table 7. Percentage of Time at Depth for the North Pacific Right Whale on Breeding Grounds, Based on Data from the Surrogate Species, the North Atlantic Right Whale

Depth Bin (m)	Percentage of Time at Depth
0-2	27.45
2-4	11.40
4-6	12.97
6-8	11.42
8-10	7.81
10-12	6.34
12-14	8.01
14-16	14.13
16-18	0.43
18-20	0.04

2.5.1.2 Family Balaenopteridae

2.5.1.2.1 Balaenoptera acutorostrata, Common Minke Whale. The common minke whale is a Tier 2 species. Minke whales are widely distributed throughout the world oceans, occurring in coastal and continental shelf waters, as well as deeper waters along the continental slope and seaward (Dorsey et al., 1990; Øien, 1990). Fish (e.g. capelin, sandlance, and herring) and planktonic crustaceans such as krill are the main components of the diet of minke whales (Haug et al., 1995). Little data have been collected on minke whale diving behavior. Dive duration averages just over one minute, up to a maximum of 13.43 minutes (Gunnlaugsson, 1989; Oien et al., 1990; Stern, 1992; Stockin et al., 2001). Dive durations vary with activity, with longer dives occurring when animals are feeding at depth (Gunnlaugsson, 1989; Hoelzel et al., 1989; Curnier, 2005). There is also limited evidence that minke whales may exhibit diurnal variation in diving behavior (Joyce et al., 1990; Stockin et al., 2001).

Blix and Folkow (1995) presented a time-depth record for a minke whale tagged off the west coast of Svalbard, and based on visual inspection of figure 2, the dive profile was divided into two depth bins and time in each depth bin was estimated. The resulting depth distribution is given in table 8.

Table 8. Depth Distribution Data Estimated from Blix and Folkow (1995) for the Common Minke Whale

Depth Bin (m)	Percentage of Time at Depth
0-25	79.7
25-65	20.3

The depth distribution data in table 8 are derived from a short (75 min) dive profile of a single animal, in which two behaviors are represented, cruising (52% of time) and foraging (48% of time). According to activity budgets of two whales given in table 9, the amount of time spent in these two behaviors can vary significantly.

Table 9. Activity Budgets for Two Common Minke Whales from Blix and Folkow (1995)

Activity	Percentage of Time in each Activity		
	Whale 2/91	Whale 2/92	Average
Feeding	73	27	50.0
Cruising	10	43	26.5
Sleeping	13	0	6.5
Unknown	4	30	17

Additionally, the animal represented in table 8 was predominantly foraging between 25–50 m, while whales in the Antarctic are associated with krill patches at a median depth of 118 m (Friedlaender et al., 2009b). Therefore, common minke whales may by capable of diving to greater depths. However, due to the paucity of available dive behavior data for minke whales, the dive depth distribution in table 8 will be considered representative for common minke whales.

2.5.1.2.2 Balaenoptera borealis, Sei Whale. The sei whale is a Tier 2 species that will be represented by a surrogate species, the Bryde’s whale (section 2.5.1.2.3). Sei whales have a cosmopolitan distribution, but migrate between high latitude feeding grounds and low latitude breeding grounds (Horwood, 2002). Sei whales feed predominantly on copepods and euphausids, which occur at the surface and down to 150 m deep (Budylenko, 1978; Flinn et al., 2002). The Bryde’s whale is the closest relative to the sei whale (Sasaki et al., 2005), is of similar body size (Horwood, 2002), and feeds on similar prey in the Northern hemisphere (Mizroch et al., 1984; Flinn et al., 2002). Sei whales differ from other Balaenopterids in their preference for copepods, similar to right whales.

Sei whales are not thought to be deep divers. Bryde’s whales also spend most of their time near the surface (Alves et al., 2010). Examination of depth distributions indicates that foraging North Atlantic right whales and Bryde’s whales utilize similar water depths (sections 2.5.1.1.2 and 2.5.1.2.3). Therefore, the sei whale will be modeled using the depth distribution for the Bryde’s whale, shown in table 10.

Table 10. Percentage of Time at Depth for the Sei Whale Based on Data from the Surrogate Species, the Bryde's Whale

Depth Bin (m)	Percentage of Time at Depth
0-40	84.5
40-292	15.3

2.5.1.2.3 Balaenoptera edeni, Bryde's Whale. The Bryde's whale is a Tier 2 species. Bryde's whales are found in tropical and temperate waters, and there may be separate coastal and offshore forms (Best, 2001; Weir, 2007). There is ongoing debate about the taxonomic relationship between two morphotypes, the larger *–brydei* form and the smaller *-edeni* form (Sasaki et al., 2006). Their main prey include pelagic schooling fish species, such as sardines, mackerel, and herring (Siciliano et al., 2004), as well as cephalopods and small crustaceans (Omura, 1962; Kato, 2002). Alves et al. (2010) reported a distribution of time spent shallow and deep diving 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 in table 11 give a reasonable approximation of the time spent in the different depth bins.

Table 11. Dive Depth Distribution Data from Alves et al. (2010) Used to Estimate Depth Distribution for the Bryde's Whale

Depth Bin (m)	Percentage of Time Diving to each Depth Range		
	Whale Bbr002	Whale Bbr003	Average
0-40	81.9	87.2	84.5
40-292	18.0	12.7	15.3

2.5.1.2.4 Balaenoptera musculus, Blue Whale. The blue whale is a Tier 1 species. Blue whales have a cosmopolitan distribution in both coastal and offshore waters. Prey species of blue whales are almost exclusively euphausids (Sears, 2002). Values used to estimate blue whale movement and diving behavior as input into 3MB are provided in table 12.

Table 12. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Blue Whale (Number Values Represent Means (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Foraging Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value (dependence on	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.2)	Best estimate
	Ascent Rate (m/s)	Gaussian 2.1 (0.52)	Croll et al. (2001)
	Descent Rate (m/s)	Gaussian 2.2 (0.38)	Croll et al. (2001)
	Average Depth (m)	Gaussian 140 (46)	Best estimate
	Bottom Following	No	Best estimate
	Reversals	Gaussian 2.4 (1.1)	Croll et al. (2001)
	Probability of Reversal	0.95	Best estimate
	Reversal Dive Ascent Rate (m/s)	2.4 (0.9)	Croll et al. (2001)
	Reversal Dive Descent Rate m/s	1.5 (0.4)	Croll et al. (2001)
	Time in Reversal (s)	15.5 (5.3)	Croll et al. (2001)
	Surface Interval (s)	Gaussian 158 (47.6)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s)	150 (40)	Best estimate
Non-Foraging Dive (Deep)	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.22	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.2)	Best estimate
	Ascent Rate (m/s)	Gaussian 2.1 (0.52)	Croll et al. (2001)
	Descent Rate (m/s)	Gaussian 2.2 (0.38)	Croll et al. (2001)
	Average Depth (m)	Gaussian 154.3 (38.8)	Croll et al. (2001)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 78 (30.2)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s)	15 (5)	Best estimate
Non-Foraging Dive (Shallow)	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.2)	Best estimate
	Ascent Rate (m/s)	Gaussian 2.1 (0.52)	Croll et al. (2001)
	Descent Rate (m/s)	Gaussian 2.2 (0.38)	Croll et al. (2001)
	Average Depth (m)	Gaussian 26.8 (1.5)	Croll et al. (2001)
	Bottom Following	No	Best estimate
	Reversals	90 (30)	Best estimate
	Probability of Reversal	1	Best estimate
	Reversal Dive Rate (m/s)	0.7 (0.2)	Best estimate, Croll et al. (2001)
	Time in Reversal (s)	1 (0.2)	Best estimate, Croll et al. (2001)
	Surface Interval (s)	Gaussian 78 (30.2)	Acevedo-Gutiérrez et al. (2002)
	Bout duration (s; 0700-1900)	30 (10)	Best estimate
	Bout duration (s; 1900-0700)	120 (30)	Best estimate

The resulting depth distribution using the values in table 12 is provided in table 13. The time at depth is consistent with foraging dives to 130–150 m (Schoenherr, 1991) and 135–293 m (Croll et al., 2001; Calambokidis et al., 2008) off central California, and 50–300 m off southern California (Croll et al., 2001; Acevedo-Gutiérrez et al., 2002; Oleson et al., 2007).

Table 13. Percentage of Time at Depth for the Blue Whale

Depth Bin (m)	Percentage of Time at Depth
0-15	43.078
15-30	29.621
30-45	9.376
45-60	2.334
60-75	2.342
75-90	2.341
90-105	2.264
105-120	2.094
120-135	1.859
135-150	1.528
150-165	1.187

Depth Bin (m)	Percentage of Time at Depth
165-180	0.819
180-195	0.532
195-210	0.312
210-225	0.172
225-240	0.084
240-255	0.035
255-270	0.013
270-285	0.005
285-300	0.002
300-315	0.001

2.5.1.2.5 Balaenoptera omurai, Omura's Whale. The Omura's whale is a Tier 2 species that will be represented by a surrogate species, the Bryde's whale (section 2.5.1.2.3). The Omura's whale represents a recently described species that was originally described as a small form Bryde's whale (Wada et al., 2003; Sasaki et al., 2006). Omura's whales have thus far been identified from the Sea of Japan, the Solomon Sea, and the eastern Indian Ocean (Wada et al., 2003). Omura's whales are closely related to Bryde's whales and sei whales, both of which are represented by a Bryde's whale depth distribution. Therefore, the Bryde's whale depth distribution in table 14 will be considered representative of the Omura's whale.

Table 14. Percentage of Time at Depth for the Omura's Whale Based on Data from the Surrogate Species, the Bryde's Whale

Depth Bin (m)	Percentage of Time at Depth
0-40	84.5
40-292	15.3

2.5.1.2.6 Balaenoptera physalus, Fin Whale. The fin whale is a Tier 1 species, occurring most densely in the cold and temperate waters of the globe (Aguilar 2002). Fin whales are more commonly found seaward of the continental slope (Aguilar 2002). Prey species include euphausids (Vikingsson, 1997; Ruchonnet et al., 2006; Laidre et al., 2010), schooling fish such as herring and capelin (Nottestad et al., 2002), and cephalopods (Flinn et al., 2002). Values used to estimate fin whale movement and diving behavior as input into 3MB are provided in table 15.

Table 15. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Fin Whale (Number Values Represent Means (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Shallow Foraging Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value (dependence	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.6 (0.6)	Goldbogen et al. (2006)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Goldbogen et al. (2006)
	Descent Rate (m/s)	Gaussian 3.0 (0.2)	Goldbogen et al. (2006)
	Average Depth (m)	Gaussian 46 (4.8)	Croll et al. (2001)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 3.1 (1.1)	Best estimate
	Probability of Reversal	0.95	Best estimate
	Reversal Dive Ascent Rate	Gaussian 1.7 (0.4)	Best estimate
	Reversal Dive Descent Rate m/s	Gaussian 1.4 (0.5)	Croll et al. (2001)
	Time in Reversal (s)	Gaussian 13.7 (2.8)	Croll et al. (2001)
	Surface Interval (s)	Gaussian 123.8 (42.3)	Acevedo Gutierrez et al. (2002)
	Bout duration (s)	t50 = 30, k = 15	Best estimate
Shallow Non-foraging Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.6 (0.6)	Goldbogen et al. (2006)
	Ascent Rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Descent Rate (m/s)	Gaussian 2.0 (0.2)	Croll et al. (2001)
	Average Depth (m)	Gaussian 28.2 (1.8)	Croll et al. (2001)
	Bottom Following	No	Best estimate
	Reversals	90 (30)	Best estimate
	Probability of Reversal	1	Best estimate
	Reversal Dive Ascent Rate	0.7 (0.2)	Best estimate, Croll et al. (2001)
	Time in Reversal (s)	1 (0.2)	Best estimate,Croll et al. (2001)
	Surface Interval (s)	Gaussian 80 (19.2)	Acevedo Gutierrez et al. (2002)
	Bout duration	t50 = 30, k = 15	Best estimate
Deep Non-foraging Dives	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.6 (0.6)	Best estimate
	Ascent Rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Descent Rate (m/s)	Gaussian 2.0 (0.2)	Croll et al. (2001)
	Average Depth (m)	Gaussian 120 (33.5)	Croll et al. (2001)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 80 (19.2)	Acevedo Gutierrez et al. (2002)
	Termination Formula	t_{50} = 30, k = 15	Best estimate
Foraging Deep Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 1.6 (0.6)	Goldbogen et al. (2006)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Goldbogen et al. (2006)

Table 15. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Fin Whale (Number Values Represent Means (SD) Unless Otherwise Indicated) (Cont'd)

Behavior	Variable	Value	Reference
Foraging Deep Dive (Cont'd)	Descent Rate (m/s)	Gaussian 3.0 (0.2)	Goldbogen et al. (2006)
	Average Depth (m)	Gaussian 248 (18)	Goldbogen et al. (2006)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 3.1 (1.1)	Best estimate
	Probability of Reversal	0.95	Best estimate
	Reversal Dive Ascent Rate (m/s)	Gaussian 1.7 (0.4)	Croll et al. (2001)
	Reversal Dive Descent Rate	Gaussian 1.4 (0.5)	Croll et al. (2001)
	Time in Reversal (s)	Gaussian 13.7 (2.8)	Croll et al. (2001)
	Surface Interval (s)	Gaussian 123.8 (42.3)	Acevedo Gutierrez et al. (2002)
	Termination Formula	$t_{50} = 30$, k = 15	Best estimate
General	Depth limit on Seeding (m)	400	J. Barlow
	Shore Following (m)	400	J. Barlow

The resulting depth distribution using the values in table 15 is provided in table 16. Time at depth is consistent with foraging dives to 50–120 m off Mexico (Croll et al., 2001), 100–150 m (Acevedo-Gutiérrez et al., 2002) and 220–270 m off southern California (Goldbogen et al., 2006), and 194 m in the Ligurian Sea (Panigada et al., 1999). One whale has been documented diving deeper than 420 m in the Ligurian Sea (Panigada et al., 1999), which is beyond the bounds of this depth distribution. As all other dives by fin whales are to less than 300 m, the depth distribution in table 16 represents a reasonable estimate of fin whale diving behavior.

Table 16. Percentage of Time at Depth for the Fin Whale

Depth Bin (m)	Percentage of Time at Depth
0-15	46.460
15-30	10.738
30-45	9.105
45-60	4.033
60-75	2.684
75-90	2.466
90-105	2.321
105-120	2.148
120-135	1.947
135-150	1.762
150-165	1.633

Depth Bin (m)	Percentage of Time at Depth
165-180	1.592
180-195	1.712
195-210	2.107
210-225	2.663
225-240	2.834
240-255	2.217
255-270	1.125
270-285	0.361
285-300	0.081
300-315	0.011
315-330	0.001

2.5.1.2.7 Megaptera novaeangliae, Humpback Whale. The humpback whale is a Tier 2 species. Humpback whales have a cosmopolitan distribution in the coastal and continental shelf waters of the globe. They migrate between mid- and high-latitude foraging grounds and low-latitude breeding grounds (Clapham, 2002). Humpback whales feed on a variety of organisms, including euphausids and small schooling fish (Hain et al., 1982; Laerm et al., 1997; Hazen et al., 2009) Dietz et al. (2002) reported time spent at depth for six whales tagged off West Greenland. Data from the text and visual inspection of its figure 3.10 were used to derive the depth distribution in table 17. 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% 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. However, given a lack of depth distribution data presented for those areas, the depth distribution in table 17 will be used to model humpback whales on feeding grounds.

Table 17. Percentage of Time at Depth for the Humpback Whale on the High-Latitude Feeding Grounds

Depth Bin (m)	Percentage of Time at Depth
0-4	37.0
4-20	25.0
20-35	7.0
35-50	3.0
50-100	6.0
100-150	7.0
150-200	7.5
200-300	7.195
300-400	0.27
400-500	0.035

Humpback whales have major breeding grounds in several locations, including the West Indies, Hawaii, Mexico, and Japan in the northern hemisphere (Clapham, 2002). Baird et al. (2000) reported time at depth data for 10 whales in Hawaiian waters in table 18. 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 18 represents the best estimate of time spent at depth by whales on a breeding ground.

Table 18. Percentage of Time at Depth for the Humpback Whale on the Low-Latitude Breeding Grounds

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage 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	0.2
60-70	2.14	150-160	0.23
70-80	1.66	160-170	0.15
80-90	1.97	170-180	0.09

2.5.1.3 Family Delphinidae

2.5.1.3.1 Delphinus capensis, Long-Beaked Common Dolphin. The long-beaked common dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). It was not until the mid-1990s that the long-beaked common dolphin was separated from the short-beaked common dolphin as a distinct species (Heyning and Perrin, 1994). Both species of common dolphins are sympatric in some nearshore continental shelf waters, however, short-beaked common dolphins also range farther offshore (Heyning and Perrin, 1994; Rosel et al., 1994; Jefferson et al., 2009)). Long-beaked common dolphins are thought to be coastal foragers, feeding mostly on pelagic fish, particularly those in the families Scombridae, Scianidae, and Serranidae (Niño-Torres et al., 2006). Due to the paucity of data on foraging and diving behavior of long-beaked common dolphins, this species will be treated similarly to its closest relative, the short-beaked common dolphin (section 2.5.1.3.2). Since the short-beaked common dolphin will be modeled using a surrogate species, the pantropical spotted dolphin, the long-beaked common dolphin will also be modeled with the depth distribution of the same surrogate species as shown in table 19.

Table 19. Percentage of Time at Depth for the Long-Beaked Common Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.2 Delphinus delphis, Short-Beaked Common Dolphin. The short-beaked common dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). Short-beaked common dolphins are typically found in deeper waters along the continental slope (Selzer and Payne, 1988; Cañadas and Hammond, 2008). They feed on epipelagic and mesopelagic fish and squid (Selzer and Payne, 1988) and also forage at night on vertically migrating prey associated with the deep scattering layer (Evans, 1994; Ohizumi et al., 1998; Neumann and Orams, 2003; Pusineri et al., 2007). Evans (1975; 1994) described the late afternoon and evening diving behavior of an adult female common dolphin in the Pacific Ocean. Before 1730 the dolphin mostly remained in the top 10 m, at which time it switched to a pattern of regular dives to 50 m, with a maximum dive depth of just over 200 m. Table 20 presents counts of dive depths estimated from figure 28 of Evans (1975).

Table 20. Dive Depth Data from Evans (1975) Used to Estimate Depth Distribution for the Short-Beaked Common Dolphin

Dive Depth (m)	Time of Day										Average Percentage of Dive Depths
	1600-1800		1801-2000		2001-2200		2201-2400		0001-0100		
	Count	%	Count	%	Count	%	Count	%	Count	%	
0-3	4	5.8	10	15.9	4	17	34	45.3	6	18.2	20.5
3-9	28	40.6	16	25.4	9	39	14	18.7	1	3.03	25.4
9-15	22	31.9	1	1.59	1	4.3	5	6.67	1	3.03	9.5
15-21	7	10.1	1	1.59	1	4.3	0	0	1	3.03	3.8
21-27	6	8.7	2	3.17	3	13	5	6.67	4	12.1	8.7
27-34	1	1.45	4	6.35	1	4.3	9	12	5	15.2	7.9
34-40	1	1.45	19	30.2	0	0	7	9.33	8	24.2	13.0
40-46	0	0	6	9.52	0	0	1	1.33	7	21.2	6.4
46-61	0	0	2	3.17	1	4.3	0	0	0	0	1.5
61-76	0	0	1	1.59	1	4.3	0	0	0	0	1.2
76-91	0	0	1	1.59	1	4.3	0	0	0	0	1.2
91-107	0	0	0	0	1	4.3	0	0	0	0	0.9

Pantropical spotted dolphins also make shallower dives during the day than at night, when they forage on prey associated with the deep scattering layer (Scott and Chivers, 2009). During the day, pantropical spotted dolphins spend 94% of their time in the top 20 m of the water column, while at night 95% of their time is spent in the top 50 m. Maximum dive depths for pantropical spotted dolphins are 122 m for daytime and 213 m for nighttime (Baird et al., 2001). Evans (1994) reported the maximum dive depth for three common dolphins was 257 m. Pantropical spotted dolphins and common dolphins are members of the same subfamily, Delphininae (LeDuc et al., 1999) and their behavior shows clear similarities in diving pattern, foraging behavior, and water column usage. Therefore, the short-beaked common dolphin will be modeled with a surrogate species, the pantropical spotted dolphin, using the depth distribution data in table 21.

Table 21. Percentage of Time at Depth for the Short-Beaked Common Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.3 Feresa attenuata, Pygmy Killer Whale. The pygmy killer whale is a Tier 2 species that will be represented by a surrogate species, the Risso's dolphin (2.5.1.3.6). Pygmy killer whales inhabit tropical and subtropical waters of the continental slope and farther offshore (Donahue and Perryman, 2002). Stomach contents analyses indicate that their primary prey include cephalopods and fish, although marine mammals also constitute some portion of their diet (Perryman and Foster, 1980; Mignucci-Giannoni et al., 1999). Some shallow water (less than 200 m deep) prey have also been reported, but these prey species may have been taken 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). The closest relatives to the pygmy killer whale for which diving behavior have been studied are two members of the subfamily Globicephalinae, the long-finned pilot whale and the Risso's dolphin (LeDuc et al., 1999). The pygmy killer whale (2.3 m) 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. Therefore, the pygmy killer whale will be modeled as a Risso's dolphin with the depth distribution in table 22.

Table 22. Percentage of Time at Depth for the Pygmy Killer Whale Based on Data from the Surrogate Species, the Risso's Dolphin

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

2.5.1.3.4 Globicephala macrorhynchus, Short-Finned Pilot Whale. The short-finned pilot whale is a Tier 2 species that will be represented by a surrogate species, the long-finned pilot whale (section 2.5.1.3.5). Short-finned pilot whales occur in tropical and warm-temperate waters along the continental shelf and slope (Davis et al., 1998). Aguilar Soto et al. (2008) reported a maximum dive depth of 1,019 m for 23 whales near the Canary Islands, but no indication is given of the percent of time spent above 20 m depth. Therefore, the short-finned pilot whale will be modeled with a surrogate species, the long-finned pilot whale (also in the genus Globicephala) using the depth distribution data in table 23.

Table 23. Percentage of Time at Depth for the Short-Finned Pilot Whale Based on Data from the Surrogate Species, the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth
0-17	74.4
17-35	5.2
35-53	2.2
53-101	3.8
101-149	2.8
149-197	1.8
197-299	3.4
299-401	2.6
401-599	2.9
599-797	0.9

2.5.1.3.5 Globicephala melas, Long-Finned Pilot Whale. The long-finned pilot whale is a Tier 2 species. Long-finned pilot whales are commonly found in cold-temperate continental shelf and slope waters (Buckland et al., 1993; Payne and Heinemann, 1993), where they prey on epipelagic, mesopelagic, and demersal squid and fish (Desportes and Mouritsen, 1993; Gannon et al., 1997). Maximum reported dive depths range from 648 m in the Ligurian Sea (Baird et al., 2002) to 828 m in the North Atlantic Ocean (Heide-Jorgensen et al., 2002). Long-finned pilot whales show some diurnal variation in diving behavior, with deepest dives occurring shortly after sunset (Baird et al., 2002), when the whales may target vertically-migrating prey (Baird et al., 2002).

Depth distribution data were obtained from table 2 of Heide-Jorgensen et al. (2002) and are presented in table 24. These data are consistent with depth distribution data from two juvenile pilot whales in the Northwest Atlantic Ocean (Nawojchik et al., 2003). However, since the juvenile whales were tagged and released after spending more than a year in a rehabilitation facility, the data from Heide-Jørgensen et al. (2002) will be used to create a more general depth distribution profile.

Table 24. Depth Distribution Data from Heide-Jørgensen et al. (2002) Used to Estimate Depth Distribution for the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth					
	Female	Female	Large male	Large male	Small male	Small male
0-17	80.6	79.3	73.7	65.7	78.1	67.6
18-35	3.9	5.5	2.3	3.0	6.2	10.1
36-53	1.4	1.8	1.4	1.4	1.9	5.2
54-101	2.5	3.0	3.8	4.3	2.8	6.6
102-149	2.0	2.6	4.0	3.8	1.7	2.4
150-197	1.6	1.6	3.1	1.6	1.5	1.4
198-299	2.8	1.8	4.3	6.6	2.8	1.8
300-401	2.0	1.7	3.0	4.9	2.0	1.7
402-599	2.6	1.8	3.4	4.9	2.5	2.3
600-797	0.6	0.2	1.1	2.2	0.4	1.0

Depth distribution data from table 24 were recalculated to sum to 100% for each animal in each location (on continental shelf vs. off continental shelf). The mean percentage of time at depth for all animals/conditions is presented in table 25. Note that the depth bins are of non-uniform size.

Table 25. Percentage of Time at Depth for the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth
0-17	74.4
17-35	5.2
35-53	2.2
53-101	3.8
101-149	2.8
149-197	1.8
197-299	3.4
299-401	2.6
401-599	2.9
599-797	0.9

2.5.1.3.6 Grampus griseus, Risso's Dolphin. The Risso's dolphin is a Tier 2 species. Risso's dolphins are commonly found in temperate and tropical waters along the continental slope (Green et al., 1992; Baumgartner, 1997; Azzellino et al., 2008). Vertically migrating cephalopods are presumed to be the primary food source for Risso's dolphins (Clarke and Pascoe, 1985), although little is known about their foraging or diving behavior. Wells et al. (2009) reported on the movement and diving behavior of a rehabilitated adult male dolphin that stranded on the gulf coast of Florida. Based on visual inspection of figure 5 from Wells et al. (2009), the depth distribution for Risso's dolphins was estimated for four six-hour blocks of time (table 26). The tagged animal in this study travelled through waters with a mean depth of 548 m (range: 3–2,300 m). The deepest dive recorded on the tag was in the 400–500 m depth bin, and less than 0.1% of dives were to depths deeper than 200 m (Wells et al., 2009).

Table 26. Depth Distribution Data from Wells et al. (2009) Used to Estimate Depth Distribution for Risso's Dolphin

Depth Bin (m)	Period of Time			
	Dawn	Day	Dusk	Night
0-1	18	33	26	22
1-2	10	15	16	13
2-10	18	14	15	19
10-50	51	36	42	45
50-100	2	1.5	0.5	0.75
100-150	0.25	0.1	0.1	0.1
150-600	0.75	0.4	0.4	0.15

The average time spent over 24 hr in these depth bins was calculated and is presented in table 27. Note that the depth bins are non-uniform in size.

Table 27. Percentage of Time at Depth for Risso's Dolphin

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

2.5.1.3.7 Lagenodelphis hosei, Fraser's Dolphin. The Fraser's dolphin is a Tier 2 species that will be represented by a surrogate species, the long-finned pilot whale (section 2.5.1.3.5). Fraser's dolphins typically inhabit tropical pelagic waters (Louella and Dolar, 2002). No data exist on diving behavior of this species. Robison and Craddock (1983) reported that the mesopelagic fish, shrimp, and squid species found in the stomach of three dolphins typically inhabit depths near 250–500 m. Fraser's dolphins in the Sulu Sea 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 greater than 600 m in depth (Dolar et al., 2003). Fraser's dolphins have also been reported herding fish near the surface (Watkins et al., 1994). Dolar et al. (1999) reported that Fraser's dolphins have myoglobin concentrations consistent with those of other deep diving marine mammals, and relative muscle masses much greater than other dolphins their size, indicative of enhanced diving ability. Therefore, despite their smaller size, the Fraser's dolphin will be modeled as a long-finned pilot whale, another species in the family Delphinidae which feeds on mesopelagic and bathypelagic prey at similar depths (Desportes and Mouritsen, 1993; Gannon et al., 1997) (table 28).

Table 28. Percentage of Time at Depth for Fraser's Dolphin Based on Data from the Surrogate Species, the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth
0-17	74.4
17-35	5.2
35-53	2.2
53-101	3.8
101-149	2.8
149-197	1.8
197-299	3.4
299-401	2.6
401-599	2.9
599-797	0.9

2.5.1.3.8 Lagenorhynchus acutus, Atlantic White-Sided Dolphin. The Atlantic white-sided dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). White-sided dolphins are found in cold temperate and sub-polar waters, ranging from the continental shelf to offshore of the continental slope (Palka et al., 1997). They feed on both epipelagic and mesopelagic fish and squid (Couperus, 1997; Weinrich et al., 2001; Doksaeter et al., 2008; Craddock et al., 2009). One stranded and rehabilitated dolphin tagged with a satellite tag containing a saltwater switch provided basic dive behavior information (Mate et al., 1994). Over a six-day period, no dives of longer than 4 minutes and no surface durations of longer than a minute occurred, and the animal spent 89% of its time beneath the surface at unknown depths. White-sided dolphins bycaught in bottom trawl and sink gillnet fisheries were caught in nets fished at a mean depth of 189.8 m (range: 55-503 m), although the exact depth at which the animals were entangled is unknown (Craddock et al., 2009). Pantropical spotted dolphins also forage on vertically migrating prey species which come to the surface layer (above 200 m) at night (Wang et al., 2003; Scott and Chivers, 2009). Therefore, due to the paucity of data on the Atlantic white-sided dolphin's diving behavior, this species will be modeled as a pantropical spotted dolphin, with the depth distribution provided in table 29.

Table 29. Percentage of Time at Depth for the Atlantic White-Sided Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.9 Lagenorhynchus albirostris, White-Beaked Dolphin. The white-beaked dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). White-beaked dolphins occur only in the temperate and subarctic North Atlantic Ocean, generally in coastal and continental shelf waters (Kinze, 2002). Fish species constitute the primary prey of white-beaked dolphins (e.g. Atlantic cod, haddock, herring, and hake); however, cephalopods and benthic crustaceans are also part of their diet (Ostrom et al., 1993; Reeves et al., 1999). They have also been observed cooperatively herding schooling fish species at the surface (Reeves et al., 1999). Pantropical spotted dolphins also forage on vertically migrating prey species which come to the surface layer (above 200 m) at night (Wang et al., 2003; Scott and Chivers, 2009). Therefore, due to the paucity of data on the white-beaked dolphin's diving behavior, this species will be modeled as a pantropical spotted dolphin, with the depth distribution provided in table 30.

Table 30. Percentage of Time at Depth for the White-Beaked Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.10 Lagenorhynchus obliquidens, Pacific White-Sided Dolphin. The Pacific white-sided dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). 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 (Kajimura and Loughlin, 1988; Miyazaki et al., 1991; Walker and Jones, 1994; Brownell et al., 1999; Morton, 2000). No reports of depth of diving were located in the literature. 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% of dives were shorter than 20 sec in duration, and dives longer than 90 sec were rare, indicating that most dives are shallow. Heise (1997) similarly reported that 70% of foraging dives were less than 15 sec in duration. Therefore, Pacific white-sided dolphins are not considered deep divers. This species is thought to feed mostly at night or in the morning (Stroud et al., 1981) when their mesopelagic prey rise to surface waters. Pantropical spotted dolphins also feed on mesopelagic, vertically migrating prey in surface waters. 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 (Hall, 1970; Baird et al., 2001; Scott and Chivers, 2009). Therefore, based on available literature, the depth distribution provided in table 31 is considered representative for the Pacific white-sided dolphin.

Table 31. Percentage of Time at Depth for the Pacific White-Sided Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.11 Lissodelphis borealis, Northern Right Whale Dolphin. The northern right whale dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). Although the northern right whale dolphin is abundant in deep, temperate waters across the North Pacific Ocean, little is known about its natural history or behavior (Leatherwood and Walker, 1979; Jefferson and Newcomer, 1993b; Forney and Barlow, 1998; Rankin et al., 2007). They are known to commonly associate with Pacific white-sided dolphins and Risso's dolphins (Jefferson and Newcomer, 1993b; Forney and Barlow, 1998), with which they show dietary overlap (Walker and Jones, 1994). Northern right whale dolphins near the southern California coast feed principally on cephalopods and a diverse variety of myctophid fish (Leatherwood and Walker, 1979; Jefferson and Newcomer, 1993a; Jefferson et al., 1994). Some evidence based on stomach contents suggests that northern right whale dolphins may dive as deep as 200 m (Fitch and Brownell, 1968; Jefferson et al., 1994). Individual northern right whale dolphins have been observed to dive for brief periods (10–75 sec), but can also remain submerged for 6.25 min (Leatherwood and Walker, 1979) to 6.5 min (Cruickshank and Brown, 1981). Northern right whale dolphins have comparatively low muscle myoglobin content among odontocetes suggesting they are not deep divers (Noren and Williams, 2000). Therefore, due to dietary similarity and frequent association with the Pacific white-sided dolphin, the northern right whale dolphin will be represented by the same surrogate, the pantropical spotted dolphin. The depth distribution is provided in table 32.

Table 32. Percentage of Time at Depth for the Northern Right Whale Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.12 Orcinus orca, Killer Whale. The killer whale is a Tier 2 species. Killer whales have a cosmopolitan distribution, but are most commonly observed in temperate, coastal waters (Ford, 2002). Killer whales feed on a range of prey, although most populations exhibit some degree of dietary specialization. In the North Eastern 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; Saulitis et al., 2000; Pitman and Ensor, 2003).

Fish-eating killer whales have been studied more extensively than mammal-eating ecotypes, although there is still limited published information on diving behavior. 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). Baird et al. (2003a) table 5 reported that seven fish-eating killer whales tagged in British Columbia waters spent most of their time in the top 30 m of the water column (table 33). This 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.

Table 33. Percentage of Time at Depth for Fish-Eating Killer Whales

Depth Bin (m)	Percentage of Time at Depth							
	Whale	Whale	Whale	Whale	Whale	Whale	Whale	Average
0-30	99.52	100	98.33	96.22	92.4	97.83	98.82	97.59
30-228	0.48	0	1.67	3.78	7.6	2.17	1.18	2.41

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 their silhouette against brighter surface waters may improve detection. Baird (1994) reported a depth distribution profile for a mammal-eating killer whale near Vancouver Island carrying a time-depth recorder for just over three hours. Table 34 presents the depth distribution as a result of visual inspection of figure 2.5.B in Baird (1994). While this profile is the result of a short-term tag carry by a single individual, it represents a better estimate of time spent at depth than applying a fish-eating killer whale as a surrogate due to the differences in their foraging tactics.

Table 34. Percentage of Time at Depth for Mammal-Eating Killer Whales

Depth Bin (m)	Percentage of Time at Depth
0-5	24
5-10	3.5
10-15	2.5
15-20	4.2
20-25	8
25-30	12
30-35	11

Depth Bin (m)	Percentage of Time at Depth
35-40	8.5
40-45	10.9
45-50	8.5
50-55	5
55-60	1.5
60-65	0.4

2.5.1.3.13 Peponocephala electra, Melon-Headed Whale. The melon-headed whale is a Tier 2 species that will be represented by a surrogate species, the Risso's dolphin (2.5.1.3.6). Melon headed whales occur in oceanic tropical and subtropical waters (Perryman et al., 1994). They feed on a variety of mesopelagic fish and cephalopod species (Jefferson and Barros, 1997; Brownell Jr. et al., 2009; Gross et al., 2009). There currently exists no information on diving behavior. The closest relatives to the melon-headed whale are the pilot whales (LeDuc et al., 1999), although pilot whales are more than twice the size of the melon headed whales. Their small size could indicate that they do not dive as deeply as their larger relatives. Therefore, melon-headed whales will be modeled as a Risso's dolphin, another member of the same subfamily, Globicephalinae, which feeds on mesopelagic prey. The representative depth distribution is provided in table 35.

Table 35. Percentage of Time at Depth for the Melon-Headed Whale, Based on Data from the Surrogate Species, the Risso's Dolphin

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

2.5.1.3.14 Pseudorca crassidens, False Killer Whale. The false killer whale is a Tier 2 species that will be represented by a surrogate species, the Risso's dolphin (2.5.1.3.6). False killer whales inhabit tropical and temperate waters along and offshore of the continental slope (Odell and McClune, 1999). Little is known about their diving or foraging behavior. Stomach contents analyses reveal 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) at depth and at the surface (Perryman and Foster, 1980; Stacey et al., 1994; Acevedo-Gutiérrez et al., 1997). Cummings and Fish (1971) estimated that false killer whales would be capable of diving to up to 500 m depth. 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 animals 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, although the timing of the tag data (daytime vs. nighttime) was not reported. The closest relatives to the false killer whale, for which diving behavior have been studied, are two members of the subfamily Globicephalinae, the long-finned pilot whale and the Risso's dolphin (LeDuc et al., 1999). False killer whales are in between these species in size, and the limited data suggest that false killer whales do not dive to the depths reported for long-finned pilot whales. Risso's dolphins and false killer whales both feed on pelagic cephalopods (Clarke and Pascoe, 1985). Therefore, the false killer whale will be modeled using the depth distribution for the Risso's dolphin as provided in table 36.

Table 36. Percentage of Time at Depth for the False Killer Whale, Based on Data from The Surrogate Species, the Risso's Dolphin

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

2.5.1.3.15 Stenella attenuata, Pantropical Spotted Dolphin. The pantropical spotted dolphin is a Tier 2 species. Pantropical spotted dolphins are found in warm temperate and tropical waters over and offshore of the continental slope (Perrin and Hohn, 1994). They feed on both epipelagic and mesopelagic fish and squid (Wang et al., 2003). The maximum daytime and nighttime dive depths reported are 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% of all dives from 12 animals carrying time-depth recorders. Daytime dives are primarily shallow and above the thermocline (Scott and Chivers, 2009). Pantropical spotted dolphins dive deeper at night, when they forage on prey associated with vertical migrations of the deep scattering layer (Robertson and Chivers, 1997; Scott and Chivers, 2009). Water depths associated with tagged dolphins ranged 70–440 m, and no dives near the bottom were reported (Baird et al., 2001). Depth distribution data were estimated from the text, figure 4, and table 2 of Baird et al. (2001) and from the text, table 2, and figure 9 of Scott and Chivers (2009) (table 37).

Table 37. Depth Distribution Data from Baird et al. (2001) and Scott and Chivers (2009) Used to Estimate Depth Distribution for the Pantropical Spotted Dolphin

Depth (m)	Day					Night		
	Baird et al. (2001)	Baird et al. (2001)	Baird et al. (2001)	Baird et al. (2001)	Scott and Chivers (2009)	Baird et al. (2001)	Baird et al. (2001)	Scott and Chivers (2009)
0-10	84	90	89	91	61	50	68	24
10-20	16	8	7	9	33	8	12	32
20-30	0	2	2	0	3	10	4	24
30-40	0	0	2	0	0.5	12	2	7
40-50	0	0	0	0	0.5	7	2	5
50-60	0	0	0	0	0.5	6	2	3
60-70	0	0	0	0	0.5	2	2	2
70-80	0	0	0	0	0.5	1	1	1
80-90	0	0	0	0	0.5	2	1	0.5
90-100	0	0	0	0	0	1	1	0.5
100-110	0	0	0	0	0	1	1	0.5
110-120	0	0	0	0	0	0	1	0.5
120-130	0	0	0	0	0	0	0.5	0
130-140	0	0	0	0	0	0	0.5	0
140-150	0	0	0	0	0	0	0.5	0
150-160	0	0	0	0	0	0	0.5	0
160-170	0	0	0	0	0	0	0.5	0
170-180	0	0	0	0	0	0	0.3	0
180-190	0	0	0	0	0	0	0.2	0

Baird et al. (2001) reported the daytime average percentage of time in 2-m intervals for the top 10 m. For the Baird et al. (2001) nighttime and Scott and Chivers (2009) data, the percentage of time determined for the top 10 m was uniformly distributed across these 2-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 38. Note that the depth intervals are smaller for the first 5 depth bins (2 m) than the rest (10 m).

Table 38. Percentage of Time at Depth for the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage of Time at Depth		
	Day	Night	24 hour
0-2	32.6	8.3	20.4
2-4	13.0	8.3	10.7
4-6	8.9	8.3	8.6
6-8	9.7	8.3	9.0
8-10	10.7	8.3	9.5
10-20	21.5	21.0	21.3
20-30	2.0	15.5	8.8
30-40	0.5	7.0	3.8
40-50	0.3	4.8	2.5
50-60	0.3	3.5	1.9
60-70	0.3	2.0	1.1
70-80	0.3	1.0	0.6

Depth Bin (m)	Percentage of Time at Depth		
	Day	Night	24 Hour
80-90	0.3	1.0	0.6
90-100	0	0.8	0.4
100-110	0	0.8	0.4
110-120	0	0.5	0.3
120-130	0	0.1	0.1
130-140	0	0.1	0.1
140-150	0	0.1	0.1
150-160	0	0.1	0.1
160-170	0	0.1	0.1
170-180	0	0.1	0
180-190	0	0.1	0

2.5.1.3.16 Stenella clymene, Clymene Dolphin. The Clymene dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). Clymene dolphins are found in deep tropical and warm temperate waters beyond the continental shelf (Jefferson, 2002a). Limited information about their prey suggests they primarily feed on squid and vertically migrating fish of the Myctophidae family, which are associated with the deep scattering layer (Perrin et al., 1981). No information currently exists about their diving behavior. Some authors have speculated that their size limits them to the upper 250 m of the water column (Davis et al. 1998), although preliminary evidence suggests similarly-sized striped dolphins are capable of diving much deeper (Minamikawa et al., 2003). However, due to the paucity of data, the Clymene dolphin will be modeled with a surrogate species, the pantropical spotted dolphin (also in the genus Stenella), using the depth distribution data in table 39.

Table 39. Percentage of Time at Depth for the Clymene Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.17 Stenella coeruleoalba, Striped Dolphin. The striped dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). Striped dolphins prefer tropical and warm temperate waters and have an oceanic distribution with most observations occurring beyond the continental shelf (Perrin et al., 1994b; Davis and Fargion, 1996b; Davis et al., 1998; Archer II, 2002; Cañadas et al., 2002). Little is known about their foraging or diving behavior. 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 to early night 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). A single striped dolphin carrying a time-depth recorder dove to a mean depth (± SD) of 22.6 m (17.5) during the day and 126.7 m (120.9) at night, with a maximum dive depth of 705 m (Minamikawa et al., 2003). This pattern of shallow daytime shallow diving and deeper nighttime diving is consistent with similar diving behavior seen in short-beaked common dolphins (section 2.5.1.3.1) and pantropical spotted dolphins (section 2.5.1.3.15). Additionally, all three species occur in similar water depths (Davis et al., 1998). Therefore, although the striped dolphin may dive on average to deeper depths, this species will be modeled with a surrogate species, the pantropical spotted dolphin (also in the genus *Stenella*), using the depth distribution data in table 40.

Table 40. Percentage of Time at Depth for the Striped Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.18 Stenella frontalis, Atlantic Spotted Dolphin. The Atlantic spotted dolphin is a Tier 2 species that is usually found in shallow, continental shelf waters (mean depth of occurrence in the Gulf of Mexico was 197.1 m (Davis et al., 1998). Atlantic spotted dolphins are known to feed on both mesopelagic fish and squid, as well as benthic invertebrates (Perrin et al., 1994a). Davis et al. (1996) tracked a tagged dolphin in a mean water depth of 32.6 m (range 12–63 m) and indicated that it consistently dove deep enough to reach the seafloor. The maximum dive depth is between 40–60 m (Davis et al., 1996). Davis et al. (1996) reported no diel pattern in the depth of dives. This is consistent with tagging results from Griffin (2005), who reported dolphins diving to the seafloor at 30 m, with animals spending most of their time in the top 10 m. Depth distribution data were obtained from table 1 of Davis et al. (1996) and are presented in table 41.

Table 41. Percentage of Time at Depth for the Atlantic Spotted Dolphin

Depth Bin (m)	Percentage of Time at Depth
0-10	76.2
10-20	11.4
20-30	8.3
30-40	2.9
40-60	1.4

2.5.1.3.19 Stenella longirostris, Spinner Dolphin. The spinner dolphin is a Tier 2 species that will be represented by a surrogate species, the pantropical spotted dolphin (section 2.5.1.3.15). Spinner dolphins typically reside in tropical, pelagic waters, although they have a coastal distribution around the Hawaiian and French Polynesia islands (Benoit-Bird and Au, 2003). Their prey consists of vertically migrating mesopelagic fish, cephalopods, and crustaceans (Dolar et al., 2003; Lammers, 2004). They also feed on pelagic organisms concentrated in near-surface waters with a shallow thermocline (Reilly, 1990; Lammers, 2004). Many of the vertically migrating prey species spend daytime hours at depths from 700–3,000 m but move to depths from 200 m up to the surface at night. Spinner dolphins in Hawaiian waters mostly forage at dusk and early night in deep water, but dive to much shallower depths due to their prey moving closer to the surface (Benoit-Bird and Au, 2003; Lammers, 2004).

No depth distribution data exist for spinner dolphins. However, 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. Therefore, the spinner dolphin will be modeled with a surrogate species, the pantropical spotted dolphin, using the depth distribution in table 42.

Table 42. Percentage of Time at Depth for the Spinner Dolphin Based on Data from the Surrogate Species, the Pantropical Spotted Dolphin

Depth Bin (m)	Percentage 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)	Percentage 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

2.5.1.3.20 Steno bredanensis, Rough-Toothed Dolphin. The rough-toothed dolphin is a Tier 2 species. Rough-toothed dolphins are commonly found in waters along the continental shelf (Davis et al., 1998). Rough-toothed dolphins have been reported feeding near the surface, which may indicate that they primarily make shallow dives (Lodi and Hetzel, 1999; Pitman and Stinchcomb, 2002). There is little information about their diving and foraging behavior. Watkins et al. (1987) reported rough-toothed dolphins rubbing along a deployed hydrophone at a depth of 70 m. Wells et al. (2008) reported time-at-depth data from four rehabilitated and released adult rough-toothed dolphins in the Atlantic Ocean. Table 43 presents 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 dolphins spend the majority of their time in the upper 25 m of the water column. Only two of the animals made a total of three dives to the 200–300 m depth bin, and dives were generally shallowest during the daytime.

Table 43. Dive Depth Distribution Data from Wells et al. (2008) Used to Estimate Depth Distribution for the Rough-Toothed Dolphin

Depth bin	Percentage of dives to greater than 2 m depth			
	54612	57604	42480	42481
2-10	75.82	77.42	82.71	76.02
10-25	15.79	15.64	14.25	19.28
25-50	4.85	4.62	1.78	3.99
50-75	1.45	1.16	0.68	0.42
75-100	0.31	0.3	0.27	0.26
100-150	0.06	0.1	0.23	0.03
150-200	0	0	0.04	0
200-300	0.01	0	0.04	0

The data in table 43 were averaged across all four animals to give a mean depth distribution (table 44). Although these data were collected from rehabilitated animals, the paucity of data on diving behavior of healthy animals necessitates that these data are used until better information becomes available. Note that the depth bin sizes in table 44 are non-uniform.

Table 44. Percentage of Time at Depth for the Rough-Toothed Dolphin

Depth bin (m)	Percentage of Time at Depth
0-10	77.99
10-25	16.24
25-50	3.81
50-75	0.93
75-100	0.29
100-150	0.11
150-200	0.01
200-300	0.01

2.5.1.3.21 Tursiops truncatus, Bottlenose Dolphin. The bottlenose dolphin is a Tier 1 species. 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 ranging behavior (Wells and Scott 2002). Bottlenose dolphins feed primarily on fish species with squid and other invertebrates contributing to the diet as well. Due to the range of habitats in which bottlenose dolphins are found, prey species may be epipelagic, pelagic, mesopelagic, or benthic in origin (Mead and Potter, 1990; Shane, 1990; Rossbach and Herzing, 1997; Wells and Scott, 1999). Values used to estimate bottlenose dolphin movement and diving behavior as input into 3MB are provided in table 45.

Table 45. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Bottlenose Dolphin (Number Values Represent Means (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Foraging	Travel Direction	Vector model	Ward (1999)
	Travel Rate (m/s)	Vector model	Ward (1999)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent Rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average Depth (m)	Gaussian 25 (5)	Hastie et al. (2006)
	Bottom Following	Yes	Best estimate
	Reversals	Gaussian 18 (1.1)	Best estimate
	Probability of Reversal	0.09	Best estimate
	Reversal Dive Rate	Gaussian 1.0 (0.2)	Best estimate
	Time in Reversal	Gaussian 1 (0.1)	Best estimate
	Surface Interval (s)	Gaussian 46.4 (2.5)	Lopez (2009)
Playing	Travel Direction	Vector model	Ward (1999)
	Travel Rate (m/s)	Vector model	Ward (1999)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent Rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average Depth (m)	Gaussian 7 (3)	Hastie et al. (2006), Wursig and Wursig (1979)
	Bottom Following	Yes	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 3 (2)	Best estimate
Resting	Travel Direction	Vector model	Ward (1999)
	Travel Rate (m/s)	Vector model	Ward (1999)
	Ascent Rate (m/s)	Gaussian 0.5 (0.1)	Best estimate
	Descent Rate (m/s)	Gaussian 0.5 (0.1)	Best estimate
	Average Depth (m)	Uniform 2	Best estimate
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 3 (2)	Best estimate
Socializing	Travel Direction	Vector model	Ward (1999)
	Travel Rate (m/s)	Vector model	Ward (1999)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)
	Descent Rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average Depth (m)	Uniform 10	Hastie et al. (2006) Wursig and Wursig (1979)
	Bottom Following	Yes	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 3 (2)	Best estimate
Travel	Travel Direction	Vector model	Ward (1999)
	Travel Rate (m/s)	Vector model	Ward (1999)
	Ascent Rate (m/s)	Gaussian 2.1 (0.3)	Houser et al. (2010)

Table 45. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Bottlenose Dolphin (Number Values Represent Means (SD) Unless Otherwise Indicated) (Cont'd)

Travel (Cont'd)	Descent Rate (m/s)	Gaussian 1.6 (0.2)	Houser et al. (2010)
	Average Depth (m)	Gaussian 7 (3)	Hastie et al. (2006) Wursig and Wursig (1979)
	Bottom Following	Yes	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 3 (2)	Best estimate
General	Depth limit on seeding (m)	2	Wursig and Wursig (1979)
	Shore following (m)	2	Wursig and Wursig (1979)

The resulting depth distribution using the values in table 45 is provided in table 46. These data are consistent with animals foraging to 50 m in the North Atlantic Ocean (Hastie et al., 2006), and with Tursiops sp. diving to 8 m near Western Australia (Sargeant et al., 2007). While Klatsky et al. (2007) reported dolphins near Bermuda diving to depths in excess of 500 m, 50–90% of dives were to shallower than 50 m, depending on time of day.

Table 46. Percentage of Time at Depth for the Bottlenose Dolphin

Depth bin (m)	Percentage of Time at Depth
0-5	74.21
5-10	17.04
10-15	3.09
15-20	1.41
20-25	1.87
25-30	1.59
30-35	0.66
35-40	0.12
40-45	0.01

2.5.1.4 Family Eschrichtiidae

2.5.1.4.1 Eschrichtius robustus, Gray Whale. The gray whale is a Tier 2 species. Gray whales are distributed coastally in the Pacific Ocean, migrating annually between Arctic and subtropical waters (Swartz, 1986; Jones and Swartz, 2002). Foraging occurs primarily in the summer and fall, on the polar and subpolar feeding grounds and along the northern portion of their migratory route. Gray whales forage within the water column with modified skimming techniques to capture neritic fish prey, and habitually scrape the benthos to acquire benthic fish, squid, annelids, crustaceans, and mollusks (Nerini, 1984; Darling et al., 1998; Dunham and Duffus, 2002; Jones and Swartz, 2002). Gray whales have been reported foraging in water up to 120 m deep (Würsig et al., 1986; Cacchione et al., 1987; Dunham and Duffus, 2002), although in many areas whales forage in waters less than 20 m deep (Ljungblad et al., 1987; Guerrero, 1989; Malcolm et al., 1995; Malcolm and Duffus, 2000; Stewart et al., 2001; Woodward and Winn, 2006).

Little detailed information on depth distribution within the water column exists for gray whales. Malcolm et al. (1995) reported the percentage of time at depth for a single foraging whale carrying a tag for over 8 hr in British Columbia waters. Visual inspection of figure 3 from Malcolm et al. (1995) resulted in the depth distribution in table 47. The majority of dives (76%) were ventilation dives to a mean depth of 2.3 m, while 13% were feeding dives to a mean depth of 16.7 m (mean bottom depth 18 m). The whale appeared to spend little time in the water column at intermediate depths. These data compare to a later study with a larger sample size of whales, where 79% of dives by whales off Vancouver Island were to a mean depth of 2.2 m, and 15% of dives were to a mean depth of 12–19 m (Malcolm and Duffus, 2000). Wood 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 is also consistent with other studies in the same region (14.2% and 17.5%; Stelle et al., 2008) and in the Bering Sea (22%; Würsig et al., 1986). Furthermore, the dive depth is similar to the reported foraging depths in British Columbia and other regions (Ljungblad et al., 1987; Guerrero, 1989; Malcolm et al., 1995; Malcolm and Duffus, 2000; 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% of dives were less than 10 m deep (compared to 52% in table 47). 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 depth distribution given in table 47.

Table 47. Percentage of Time at Depth for the Gray Whale

Depth Bin (m)	Percentage of Time at Depth
0-2	19.5
2-4	19.5
4-6	2.0
6-8	6.5
8-10	4.5
10-12	2.5
12-14	3.5
14-16	12.5
16-18	8.5
18-20	19.5
20-22	1.5

Diving behavior on the breeding grounds is less well described. Females with calves in San Ignacio Lagoon, Baja California, Mexico, dove to a maximum depth of 20.75 m (Ludwig and Culik, 2001). Ludwig et al. (2001) reported a maximum dive depth of 27.4 m in a broader study. These depths are consistent with those reported for the foraging gray whale in table 47; therefore, this depth distribution will represent gray whales throughout their range.

2.5.1.5 Family Kogiidae

2.5.1.5.1 Kogia breviceps, Pygmy Sperm Whale. The pygmy sperm whale is a Tier 2 species that will be represented by a surrogate species, the long-finned pilot whale (section 2.5.1.3.5).

Pygmy sperm whales have a cosmopolitan distribution in all temperate and tropical waters (Bloodworth and Odell, 2008). Most prey species are exclusively oceanic in distribution with cephalopod species contributing most to the diet (Ross, 1979; Bloodworth and Odell, 2008; Fernandez et al., 2009). Based on stomach contents analysis of stranded whales in New Zealand, Beatson (2007) concluded that pygmy sperm whales feed shallower in the water column than sperm whales, although some prey species are found at depths greater than 600 m. Ploen (2004) found that prey species from South African stranded pygmy sperm whale stomachs are found at depths below 300 m. The long-finned pilot whale is another teutophagus species (Desportes and Mouritsen, 1993; Gannon et al., 1997) which forages deep in the water column (Heide-Jorgensen et al., 2002). The broad similarity in prey types and oceanic habitat suggests similarity in diving behavior, and, therefore, the depth distribution in table 48 will represent the pygmy sperm whale.

Table 48. Percentage of Time at Depth for the Pygmy Sperm Whale Based on Data from the Surrogate Species, the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth
0-17	74.4
17-35	5.2
35-53	2.2
53-101	3.8
101-149	2.8
149-197	1.8
197-299	3.4
299-401	2.6
401-599	2.9
599-797	0.9

2.5.1.5.2 Kogia sima, Dwarf Sperm Whale. The dwarf sperm whale is a Tier 2 species that will be represented by a surrogate species, the long-finned pilot whale (section 2.5.1.3.5). Dwarf sperm whales have a cosmopolitan distribution in all temperate and tropical waters (Willis and Baird, 1998). 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). Yet prey species of dwarf sperm whales are still deep in the water column with some species found below 400 m (Wang et al., 2002). Therefore, similarly to the pygmy sperm whale, the dwarf sperm whale will be modeled as a long-finned pilot whale.

Table 49. Percentage of Time at Depth for the Dwarf Sperm Whale Based on Data from the Surrogate Species, the Long-Finned Pilot Whale

Depth Bin (m)	Percentage of Time at Depth
0-17	74.4
17-35	5.2
35-53	2.2
53-101	3.8
101-149	2.8
149-197	1.8
197-299	3.4
299-401	2.6
401-599	2.9
599-797	0.9

2.5.1.6 Family Monodontidae

2.5.1.6.1 Delphinapterus leucas, Beluga Whale. The beluga whale is a Tier 2 species that will be represented by a surrogate species, the narwhal (section 2.5.1.6.2), for part of its range. Belugas occupy shallow and deep waters of the Arctic and sub-Arctic (Brodie, 1989; O'Corry-Crowe, 2002). In the spring and early summer, belugas migrate into shallow, estuarine waters, where they spend time during their seasonal molt. In many areas, belugas then leave the estuaries and range farther offshore into deep water. In the fall and winter, belugas in most areas migrate in the direction of the advancing polar ice cap, overwintering on feeding grounds both at the ice edge and some distance into the fast ice (Brodie, 1989). Beluga whales feed on a variety of prey species, including coastal fish and mesopelagic and benthic fish, cephalopods, and crustaceans (Seaman et al., 1982; Welch et al., 1993; Heide-Jørgensen and Teilmann, 1994; Dahl et al., 2000).

Heide-Jørgensen et al. (2001) reported the percentage of time spent at depth for belugas in estuarine waters provided in table 50. The deepest depth category given in Heide-Jørgensen et al. (2001) was ">20m," and the depth of the study area was not reported. Therefore, a maximum depth of 50 m is assigned for time spent in shallow waters, based on descriptions by other authors (Brodie, 1989).

Table 50. Percentage of Time at Depth for the Beluga Whale in Shallow, Coastal Waters

Depth Bin (m)	Percentage of Time at Depth
0-1	13.3
1-2	72.8
2-4	7.5
4-6	2.8
6-8	1.3
8-10	0.6
10-20	0.8
20-50	0.9

Beluga whales in the North Atlantic Ocean are sympatric with their closest relative, the narwhal, which also makes seasonal migrations in association with the polar ice cap movement (Hay and Mansfield, 1989). Narwhals feed on pelagic and benthic fish, cephalopods, and crustaceans, such as Arctic cod, Greenland halibut, and deepwater shrimp species, and there is substantial overlap in their diet with beluga whales (Thiemann et al., 2008). No depth distributions have been published for beluga whales in offshore areas. Richard et al. (2001) reported the percentage of dives to different depths during the summer in the Canadian High Arctic. These data are compared to the percentage of time spent at depth by narwhals on their summer foraging grounds table 51.

Table 51. Comparison of Percentage of Time at Depth for Narwhals and Percentage of Dives to Different Depths for Beluga Whales on Summer Foraging Grounds

Depth Bin (m)	Beluga whale	Narwhal
0-50	80.3	72.11
50-100	4.65	5.30
100-200	6.025	6.00
200-400	3.4	10.60
400-600	3.62	3.91
600-800	1.925	1.81
800-1500	0.08	0.28

The summertime distribution of time at depth and dive depth for the narwhal and beluga, respectively, are quite similar. Therefore, in the absence of time-at-depth information for the beluga whale, this species will be modeled using the depth distribution of the narwhal for offshore summer and winter foraging grounds, and during migration between those grounds provided in table 52. This distribution is also consistent with belugas diving to 872 m in the Canadian Arctic in late summer (Heide-Jorgensen et al., 1998).

Table 52. Percentage of Time at Depth for the Beluga Whale in Offshore Areas, Based on Data from the Surrogate Species, the Narwhal

Depth Bin (m)	Behavior/Season		
	Summer	Migration	Winter
0-50	72.11	62.81	53.40
50-100	5.30	4.74	6.68
100-200	6.00	7.10	8.90
200-400	10.60	12.54	10.99
400-600	3.91	6.13	5.84
600-800	1.81	3.90	4.45
800-1500	0.28	2.79	9.74

2.5.1.6.2 Monodon monoceros, Narwhal. The narwhal is a Tier 2 species. Narwhals are found in deep Arctic waters of the North Atlantic Ocean, with small numbers found in the Pacific Arctic (Hay and Mansfield, 1989; Heide-Jorgensen, 2002). Narwhals have a seasonal migration that follows the advancement and retreat of fast and pack ice. Narwhals are sympatric with their closest relative, the beluga whale, in all seasons except for summer, when beluga whales move into shallow coastal waters. Narwhals move closer to shore in the summer months, but not into the estuarine waters inhabited by beluga whales (Laidre et al., 2002). The primary prey of narwhals includes pelagic and benthic fish (e.g. Arctic cod, polar cod, and Greenland halibut), cephalopods (e.g. Gonatus species) and shrimp (Hay and Mansfield, 1989; Welch et al., 1993; Laidre and Heide-Jørgensen, 2005).

Laidre et al. (2002) and Martin et al. (1994) report the time at depth for three narwhals on the coastal summering grounds, which is presented in table 53. This depth distribution is appropriate for coastal areas of the Canadian High Arctic and Greenland (Laidre et al., 2002).

Table 53. Percentage of Time at Depth for the Narwhal on the Coastal Summering Grounds

Depth Bin (m)	Laidre et al. (2002) Whale 1	Laidre et al. (2002) Whale 2	Martin et al. 1994	Average
0-1	2.3	12.5	44.7	19.83
1-3	10.6	30.1	6.2	15.63
3-5	17.4	10.3	4.8	10.83
5-11	20.4	21.2	7.5	16.37
11-20	7.0	15.4	7.3	9.90
20-50	21.6	7.1	6.2	11.63
50-100	14.1	1.5	2.8	6.13
100-200	6.0	1.5	7.2	4.90
200-300	0.4	0.5	13.2	4.70

Narwhals spend most of their time in deeper waters offshore during the winter and while migrating between summer and winter grounds, and in some coastal locations, where waters can reach > 1,000 m deep. Laidre et al. (2003) reported the average absolute time spent in different depth bins during summer, migration, and winter movements for three narwhal subpopulations. These data were converted to percentage of time at depth and are given in table 54. The depth distribution in table 53 is appropriate for shallow summering grounds; the depth distribution in table 54 is appropriate for summering grounds with deeper waters, and for wintering grounds and migration corridors.

Table 54. Percentage of Time at Depth for the Narwhal in Deep Water Summer and Winter Locations, and During Migrations Between Them

Depth Bin (m)	Season		
	Summer	Migration	Winter
0-50	72.11	62.81	53.40
50-100	5.30	4.74	6.68
100-200	6.00	7.10	8.90
200-400	10.60	12.54	10.99
400-600	3.91	6.13	5.84
600-800	1.81	3.90	4.45
800-1500	0.28	2.79	9.74

2.5.1.7 Family Phocoenidae

2.5.1.7.1 Phocoena phocoena, Harbor Porpoise. The harbor porpoise is a Tier 1 species. Harbor porpoise inhabit temperate and sub-arctic continental shelf waters of the northern hemisphere. Fish constitute their primary prey, including both pelagic schooling and benthic species (Recchia and Read, 1989; Bjorge and Tolley, 2002). Cephalopods, crustaceans, euphausids, and polychaetes also contribute to the overall diet (Recchia and Read, 1989; Smith and Read, 1992; Walker et al., 1998). Values used to estimate harbor porpoise movement and diving behavior as input into 3MB are given in table 55.

Table 55. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Harbor Porpoise (Number Values Represent Means (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Nighttime diving	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	Gaussian 0.9 (0.3)	Otani et al. (2000)
	Ascent Rate (m/s)	Gaussian 1.34 (0.53)	Westgate et al. (1995)
	Descent Rate (m/s)	Gaussian 1.44 (0.51)	Westgate et al. (1995)
	Average Depth (m)	Gaussian 37.5 (12.5)	Westgate et al. (1995)
	Bottom Following	Yes	Best estimate
	Reversals	Gaussian 1 (0)	Best estimate
	Probability of Reversal	0.84	Westgate et al. (1995)
	Reversal Dive Rate (m/s)	0 (0)	Best estimate
	Time in Reversal (s)	Gaussian 10.3 (13.9)	Westgate et al. (1995)
	Surface Interval (s)	Gaussian 31.6 (73.8)	Otani et al. (1998; 2000)
Daytime Diving	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	Gaussian 0.9 (0.3)	Otani et al. (2000)
	Ascent Rate (m/s)	Gaussian 0.87 (0.38)	Westgate et al. (1995)
	Descent Rate (m/s)	Gaussian 0.99 (0.34)	Westgate et al. (1995)
	Average Depth (m)	Gaussian 22.5 (11.6)	Westgate et al. (1995)
	Bottom Following	Yes	Best estimate
	Reversals	Gaussian 1 (0)	Best estimate
	Probability of Reversal	0.84	Westgate et al. (1995)
	Reversal Dive Rate (m/s)	0 (0)	Best estimate
	Time in Reversal (s)	Gaussian 20.5 (27.8)	Westgate et al. (1995)
	Surface Interval (s)	Gaussian 31.6 (73.8)	Otani et al. (1998; 2000)
General	Depth limit on seeding (m)	200	Osmek et al. (1993)

The resulting depth distribution using the values in table 55 is provided in table 56. Time at depth is consistent with Cooper (1993), who 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) similarly reported porpoises diving to a maximum of 226 m, but the average dive depth for individual porpoises ranged 14–41 m, and the depth range with the greatest proportion of dives was 2–10 m. Porpoises off the coast of Japan spent 74–86% of their time in the top 20 m of the water column with an average dive depth of 12–19 m (Otani et al., 1998).

Table 56. Percentage of Time at Depth for the Harbor Porpoise

Depth Bin (m)	Percentage of Time at Depth
0-15	68.45
15-30	18.32
30-45	9.99
45-60	2.86
60-75	0.37

2.5.1.7.2 Phocoenoides dalli, Dall's Porpoise. The Dall's porpoise is a Tier 2 species. Their distribution is limited to the subarctic and cool temperate North Pacific Ocean, including the Bering Sea, Okhotsk Sea, and Sea of Japan (Jefferson, 2002b). Primary prey species include epipelagic and mesopelagic schooling fish and cephalopod species (Stroud et al., 1981; Jefferson, 1988; Walker, 1996; Ohizumi et al., 2000). Baird and Hanson (1998) tagged three Dall's porpoises with time-depth recorders in the transboundary waters between Washington State and British Columbia. Based on visual inspection of figures 3 and 4 of Baird and Hanson (1998), the individual and average depth distributions were estimated and are presented in table 57. All of the animals had a median dive depth of less than 40 m. Maximum dive depths ranged 197–278 m. The diving depths are consistent with stomach contents analyses which suggest 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., 2003).

Table 57. Percentage of Time at Depth for the Dall's Porpoise

Depth Bin (m)	Percentage of Time at Depth			
	Tag 97-01	Tag 97-02	Tag 97-03	Average
0-1	0.5	12.5	3.0	5.33
1-2	4.25	26.25	16.5	15.67
2-3	10.5	9.25	6.75	8.83
3-4	6.25	2.25	1.0	3.17
4-5	7.25	2.5	1.5	3.75
5-6	2.5	1.5	1.0	1.67
6-7	1.5	0.75	0.75	1.00
7-8	2.25	1.0	0.75	1.33
8-9	2.0	0.75	1.0	1.25
9-10	3.25	1.0	1.25	1.83
10-11	2.25	0.75	1.0	1.33
11-20	17.0	8.0	10	11.67
20-30	8.0	7.5	9.5	8.33
30-40	6.5	6.5	7.5	6.83
40-50	3.5	6.0	9.0	6.17
50-60	1.75	4.0	8.5	4.75
60-70	2.0	2.25	9.75	4.67
70-80	3.0	3.0	5.5	3.83
80-90	1.75	2.0	3.0	2.25
90-100	3.0	1.75	1.25	2.00
100-110	1.75	0.5	1.0	1.08
110-120	1.5	0	0.5	0.67
120-130	1.25	0	0	0.42
130-140	1.5	0	0	0.50
140-150	1.25	0	0	0.42
150-160	1.0	0	0	0.33
160-170	0.75	0	0	0.25
170-180	1.0	0	0	0.33
180-190	0.75	0	0	0.25
190-200	0.25	0	0	0.08

2.5.1.8 Family Physeteridae

2.5.1.8.1 Physeter macrocephalus, Sperm Whale. The sperm whale is a Tier 1 species. This species 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 (Kawakami, 1980; Martin and Clarke, 1986; Fiscus et al., 1989; Flinn et al., 2002). Values used to estimate sperm whale movement and diving behavior as input into 3MB are provided in table 58.

Table 58. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Sperm Whale (Number Values Represent Means (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Deep Foraging Dive	Travel Direction	correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.88 (0.27)	Miller et al. (2004)
	Ascent Rate (m/s)	Atlantic: Gaussian 1.4 (0.2) Gulf of Mexico: Gaussian 1.3 (0.2) Pacific: Gaussian 1.2 (0.2)	Watwood et al. (2006) Watwood et al. (2006) Aoki et al. (2007)
	Descent Rate (m/s)	Atlantic: Gaussian 1.2 (0.1) Gulf of Mexico: Gaussian 1.1 (0.2) Pacific: Gaussian 1.2 (0.2)	Watwood et al. (2006) Watwood et al. (2006) Aoki et al. (2007)
	Average Depth (m)	Atlantic: Gaussian 683.7 (83.1) Gulf of Mexico: Gaussian 546.9 (130) Pacific: Gaussian 616.6 (217.9)	Watwood et al. (2006) Watwood et al. (2006) Aoki et al. (2007)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 8.2 (4.2)	Aoki et al. (2007)
	Reversal Dive Rate (m/s)	Gaussian 1.8 (0.5)	Aoki et al. (2003)
	Time in Reversal (s)	Gaussian 141.0 (82.7)	Aoki et al. (2003) Amano et al. (2003)
	Surface Interval (s)	Atlantic: Gaussian 558 (168) Gulf of Mexico: Gaussian 486 (156) Pacific: Gaussian 510 (133.8)	Watwood et al. (2006) Watwood et al. (2006) Amano and Yoshioka (2003)
Inactive Bottom Time	Travel Direction	correlated random walk	Best estimate
	Perturbation	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.88 (0.27)	Miller et al. (2004)
	Ascent Rate (m/s)	Gaussian 1.13 (0.07)	Amano and Yoshioka (2003)
	Descent Rate (m/s)	Gaussian 1.4 (0.13)	Amano and Yoshioka (2003)
	Average Depth (m)	Gaussian 490 (74.6)	Amano and Yoshioka (2003)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 1.0 (0)	Best estimate
	Reversal Dive Rate (m/s)	0.1 (0.1)	Best estimate
	Time in Reversal (s)	Gaussian 1188 (174.6)	Amano and Yoshioka (2003)
	Surface Interval (s)	Gaussian 546 (354)	Amano and Yoshioka (2003)
V Dive	Travel Direction	correlated random walk	Best estimate
	Perturbation value	10	Best estimate

Table 58. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Sperm Whale (Number Values Represent Means (SD) Unless Otherwise Indicated) (Cont'd)

Behavior	Variable	Value	Reference
V Dive (Cont'd)	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.88 (0.27)	Miller et al. (2004)
	Ascent Rate (m/s)	Gaussian 0.67 (0.43)	Amano and Yoshioka (2003)
	Descent Rate (m/s)	Gaussian 0.85 (0.05)	Amano and Yoshioka (2003)
	Average Depth (m)	Gaussian 282.7 (69.9)	Amano and Yoshioka (2003)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 408 (114)	Amano and Yoshioka (2003)
Surface Inactive (Head Down)	Travel Direction	correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.0 (0.0)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.1 (0.1)	Miller et al. (2008)
	Descent Rate (m/s)	Gaussian 0.1 (0.1)	Miller et al. (2008)
	Average Depth (m)	Gaussian 16.5 (4.9)	Miller et al. (2008)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 1.0 (0)	Best estimate
	Reversal Dive Rate	0.0 (0.0)	Best estimate
	Time in Reversal	Gaussian 804 (522)	Miller et al. (2008)
	Surface Interval	Gaussian 462 (360)	Miller et al. (2008)
	Bout Duration	t50 = 8.1, K = 0.9.	Best estimate
Surface Inactive (Head Up)	Travel Direction	correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.0 (0)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.1 (0.1)	Miller et al. (2008)
	Descent Rate (m/s)	Gaussian 0.1 (0.1)	Miller et al. (2008)
	Average Depth (m)	Gaussian 8.6 (4.8)	Miller et al. (2008)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 1.0 (0)	Best estimate
	Reversal Dive Rate (m/s)	0.0 (0.0)	Best estimate
	Time in Reversal (s)	Gaussian 708 (552)	Miller et al. (2008)
	Surface Interval (s)	Gaussian 462 (360)	Miller et al. (2008)
	Bout Duration	t50 = 8.1, K = 0.9	Best estimate
Surface Active	Travel Direction	correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 0.88 (0.27)	Miller et al. (2004)
	Ascent Rate (m/s)	Gaussian 0.67 (0.43)	Amano and Yoshioka (2003)
	Descent Rate (m/s)	Gaussian 0.85 (0.05)	Amano and Yoshioka (2003)
	Average Depth (m)	Gaussian 25.0 (25.0)	Amano and Yoshioka (2003)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 408 (114)	Amano and Yoshioka (2003)

The resulting depth distributions using the values in table 58 are provided in table 59, table 60, and table 61. To account for published differences in the foraging dive behavior of whales in the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean (Amano and Yoshioka, 2003; Watwood et al., 2006; Aoki et al., 2007), separate depth distributions were generated for these three areas. Time spent at depth for all three regions (table 59) is consistent with foraging dives to 800–1,200 m in the Western North Atlantic Ocean (Watwood et al., 2006), 400–800 m in the Gulf of Mexico (Watwood et al., 2006), 400–1,300 m in the Western North Pacific Ocean (Amano and Yoshioka, 2003; Aoki et al., 2007), and 400–1,100 in the Caribbean Sea (Watkins et al., 1993).

Table 59. Percentage of Time at Depth for the Sperm Whale in the Atlantic Ocean

Depth Bin (m)	Percentage of Time at Depth
0-50	31.25
50-100	2.82
100-150	2.91
150-200	3.13
200-250	3.33
250-300	3.58
300-350	3.86
350-400	4.36
400-450	4.98
450-500	6.03
500-550	5.76
550-600	5.27
600-650	4.14
650-700	3.57
700-750	2.81
750-800	2.25
800-850	1.84
850-900	1.53
900-950	1.31
950-1000	1.14
1000-1050	0.91
1050-1100	0.73
1100-1150	0.58
1150-1200	0.47
1200-1250	0.37
1250-1300	0.29
1300-1350	0.23
1350-1400	0.17
1400-1450	0.12
1450-1500	0.08
1500-1550	0.06
1550-1600	0.04
1600-1650	0.03
1650-1700	0.02
1700-1750	0.01
1750-1800	0.01

Table 60. Percentage of Time at Depth for the Sperm Whale in the Gulf of Mexico

Depth Bin (m)	Percentage of Time at Depth
0-50	32.81
50-100	3.45
100-150	3.74
150-200	4.07
200-250	4.42
250-300	4.65
300-350	4.86
350-400	5.17
400-450	5.18
450-500	5.41
500-550	4.89
550-600	4.31
600-650	3.16
650-700	2.48
700-750	2.01
750-800	1.68
800-850	1.39
850-900	1.18
900-950	0.99
950-1000	0.84

Depth Bin (m)	Percentage of Time at Depth
1000-1050	0.68
1050-1100	0.54
1100-1150	0.43
1150-1200	0.37
1200-1250	0.31
1250-1300	0.24
1300-1350	0.17
1350-1400	0.12
1400-1450	0.1
1450-1500	0.08
1500-1550	0.06
1550-1600	0.05
1600-1650	0.04
1650-1700	0.03
1700-1750	0.02
1750-1800	0.02
1800-1850	0.02
1850-1900	0.01
1900-1950	0.01
1950-2000	0.01

Table 61. Percentage of Time at Depth for the Sperm Whale in the Pacific Ocean

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-50	30.689	1200-1250	0.472
50-100	3.22	1250-1300	0.382
100-150	3.372	1300-1350	0.306
150-200	3.587	1350-1400	0.248
200-250	3.757	1400-1450	0.194
250-300	3.893	1450-1500	0.161
300-350	4.057	1500-1550	0.128
350-400	4.434	1550-1600	0.11
400-450	4.668	1600-1650	0.086
450-500	5.167	1650-1700	0.069
500-550	4.75	1700-1750	0.051
550-600	4.024	1750-1800	0.039
600-650	3.537	1800-1850	0.028
650-700	3.112	1850-1900	0.019
700-750	2.786	1900-1950	0.013
750-800	2.461	1950-2000	0.009
800-850	2.149	2000-2050	0.006
850-900	1.836	2050-2100	0.004
900-950	1.563	2100-2150	0.003
950-1000	1.316	2150-2200	0.002
1000-1050	1.098	2200-2250	0.002
1050-1100	0.892	2250-2300	0.002
1100-1150	0.712	2300-2350	0.001
1150-1200	0.581	2350-2400	0.001

The depth distributions for the Atlantic Ocean and Gulf of Mexico and are shallower than the deepest dives reported by Teloni et al. (2008) (1,837 m and 1,861 m), and Watkins et al. (1993) (2,035 m). All three depth distributions are shallower than the inferred dive to greater than 3,000 m by Clarke (1976); however, they do encompass the majority of reported dive behavior.

2.5.1.9 Family Ziphiidae

2.5.1.9.1 Berardius arnuxii, Arnoux's Beaked Whale. Arnoux's beaked whale is a Tier 1 species that will be represented by a surrogate species, the Cuvier's beaked whale (Section 2.5.1.9.14). Arnoux's beaked whales are found in deep cold temperate and subpolar waters of the southern hemisphere, especially in areas with steep-sloped bottoms beyond the continental shelf edge (Balcomb, 1989; Kasuya, 2002). Rogers (1999) made acoustic observations of whales near Kemp Land, Antarctica in 550–600 m of water. Their food habits are assumed to be similar to those of Baird's beaked whales which consist of benthic and pelagic fish and cephalopods (Balcomb 1989; Kasuya, 2002). Hobson and Martin (1996) reported on behavior and dive times of 17 adult whales observed at narrow cracks or leads in the ice near the Antarctic peninsula. These data are not representative of dive depth, but dive duration ranged from 35–65 min with a maximum dive duration of 70 min. Early reports by whalers suggested that Arnoux's beaked whales are capable of diving routinely to 1,000 m and occasionally below 2000 m (Balcomb, 1989). The closest related species, Baird's beaked whale (which may in fact be the same species; Balcomb, 1989), was reported to dive to depths of 1,777 m off Japan (Minamikawa et al., 2007), although the dive behavior was not fully characterized. Therefore, the Arnoux's beaked whale will be modeled with the depth distribution for the Cuvier's beaked whale, another member of the subfamily Ziphiinae, provided in table 62.

Table 62. Percentage of Time at Depth for Arnoux's Beaked Whale, Based on Data from the Surrogate Species, Cuvier's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-50	49.76	950-1000	1.13
50-100	6.38	1000-1050	1.07
100-150	5.91	1050-1100	0.93
150-200	5.03	1100-1150	0.8
200-250	3.92	1150-1200	0.74
250-300	2.95	1200-1250	0.61
300-350	2.16	1250-1300	0.49
350-400	1.63	1300-1350	0.41
400-450	1.41	1350-1400	0.29
450-500	1.36	1400-1450	0.21
500-550	1.35	1450-1500	0.22
550-600	1.28	1500-1550	0.18
600-650	1.35	1550-1600	0.15
650-700	1.41	1600-1650	0.09
700-750	1.43	1650-1700	0.07
750-800	1.33	1700-1750	0.05
800-850	1.29	1750-1800	0.03
850-900	1.28	1800-1850	0.01
900-950	1.25	1850-1900	0.01

2.5.1.9.2 Berardius bairdii, Baird's Beaked Whale. Baird's beaked whale is a Tier 1 species that will be represented by a surrogate species, Cuvier's beaked whale (section 2.5.1.9.14). 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 (Kasuya, 1986; Balcomb, 1989). 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). Stomach contents analysis suggests that whales are feeding at depths of 800–1,200 m off Japan (Walker et al., 2002). Minamaka (2007) reported that one animal carrying a time-depth recorder dove down to 1,777 m and for up to 64.4 min, which agrees with the dive duration maximum of 67 min observed by Kasuya (1986). The diving pattern of Baird's beaked whales appears very similar to Cuvier's and Blainville's beaked whales, in which a long-duration deep dive is followed by shallower and shorter dives (Tyack et al., 2006; Minamikawa, et al. 2007). Due to the incomplete characterization of the diving behavior of Baird's beaked whale in the literature, this species will be modeled with the depth distribution for the Cuvier's beaked whale, another member of the subfamily Ziphiinae, provided in table 63.

Table 63. Percentage of Time at Depth for Baird's Beaked Whale, Based on Data from the Surrogate Species, Cuvier's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-50	49.76
50-100	6.38
100-150	5.91
150-200	5.03
200-250	3.92
250-300	2.95
300-350	2.16
350-400	1.63
400-450	1.41
450-500	1.36
500-550	1.35
550-600	1.28
600-650	1.35
650-700	1.41
700-750	1.43
750-800	1.33
800-850	1.29
850-900	1.28
900-950	1.25

Depth Bin (m)	Percentage of Time at Depth
950-1000	1.13
1000-1050	1.07
1050-1100	0.93
1100-1150	0.8
1150-1200	0.74
1200-1250	0.61
1250-1300	0.49
1300-1350	0.41
1350-1400	0.29
1400-1450	0.21
1450-1500	0.22
1500-1550	0.18
1550-1600	0.15
1600-1650	0.09
1650-1700	0.07
1700-1750	0.05
1750-1800	0.03
1800-1850	0.01
1850-1900	0.01

2.5.1.9.3 Hyperoodon ampullatus, Northern Bottlenose Whale. The Northern Bottlenose whale is a Tier 1 species that will be represented by a surrogate species, Cuvier's beaked whale (section 2.5.1.9.14). Bottlenose whales are found in deep, cold-temperate and subpolar waters of the North Atlantic Ocean (Gowans, 2002). The primary prey of bottlenose whales is squid, principally those species of the genus Gonatus (Hooker et al., 2001; Santos et al., 2001b). Hooker and Baird (1999a) reported on the diving behavior of two individuals from Canadian waters. Both individuals routinely dived to deeper than 800 m with the maximum dive depth reaching 1,453 m. However, no depth distribution data were presented. Cuvier's beaked whale is another deep-diving member of the family Ziphiidae, and is of similar size to female Northern bottlenose whales (Leatherwood and Reeves, 1983). The depth distribution for the Northern bottlenose whale is provided in table 64, represented by the surrogate species, Cuvier's beaked whale.

Table 64. Percentage of Time at Depth for the Northern Bottlenose Whale, Based on Data from the Surrogate Species, Cuvier's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-50	49.76	950-1000	1.13
50-100	6.38	1000-1050	1.07
100-150	5.91	1050-1100	0.93
150-200	5.03	1100-1150	0.8
200-250	3.92	1150-1200	0.74
250-300	2.95	1200-1250	0.61
300-350	2.16	1250-1300	0.49
350-400	1.63	1300-1350	0.41
400-450	1.41	1350-1400	0.29
450-500	1.36	1400-1450	0.21
500-550	1.35	1450-1500	0.22
550-600	1.28	1500-1550	0.18
600-650	1.35	1550-1600	0.15
650-700	1.41	1600-1650	0.09
700-750	1.43	1650-1700	0.07
750-800	1.33	1700-1750	0.05
800-850	1.29	1750-1800	0.03
850-900	1.28	1800-1850	0.01
900-950	1.25	1850-1900	0.01

2.5.1.9.4 Indopacetus pacificus, Longman's Beaked Whale. Longman's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Longman's beaked whales have until recently only been known from skeletal remains of stranded animals (Moore, 1972; Pitman, 2002a), although now live sightings have been recognized as Longman's beaked whale (Pitman et al., 1999; Dalebout et al., 2003). Similar to other beaked whales, prey species most likely include cephalopods (Yamada, 2002), although nothing is known about the foraging habits of this species. Longman's beaked whales are 6–8 m long, closer in size to a Cuvier's beaked whale than the other beaked whale species. Longman's beaked whale was originally described as Mesoplodon pacificus (Pitman, 2002a), and although its taxonomic status within the Ziphiidae is unresolved (Dalebout et al., 2003), there is some evidence that it may be more closely related to Mesoplodon species (Dalebout et al., 2004). Dive times are reported to range 11–33 min, although one dive may have lasted longer than 45 min (Gallo-Reynoso and Figueroa-Carranza, 1995; Anderson et al., 2006). Due to lack of data on diving behavior, the Longman's beaked whale will be modeled with the depth distribution of the Blainville's beaked whale, provided in table 65.

Table 65. Percentage of Time at Depth for Longman's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-20	43.447
20-40	8.743
40-60	7.166
60-80	5.665
80-100	4.134
100-120	2.793
120-140	1.740
140-160	1.127
160-180	0.772
180-200	0.597
200-220	0.500
220-240	0.470
240-260	0.460
260-280	0.455
280-300	0.454
300-320	0.454
320-340	0.456
340-360	0.458
360-380	0.458
380-400	0.460
400-420	0.461
420-440	0.465
440-460	0.478
460-480	0.492
480-500	0.505
500-520	0.520
520-540	0.528
540-560	0.553
560-580	0.576
580-600	0.589
600-620	0.605
620-640	0.642
640-660	0.697
660-680	0.715
680-700	0.708
700-720	0.694
720-740	0.727
740-760	0.739
760-780	0.741
780-800	0.758
800-820	0.781
820-840	0.775
840-860	0.694
860-880	0.624
880-900	0.601
900-920	0.566
920-940	0.512
940-960	0.444
960-980	0.384
980-1000	0.330
1000-1020	0.285
1020-1040	0.228
1040-1060	0.182
1060-1080	0.146
1080-1100	0.110
1100-1120	0.078
1120-1140	0.057
1140-1160	0.048
1160-1180	0.050
1180-1200	0.045
1200-1220	0.030
1220-1240	0.015
1240-1260	0.004
1260-1280	0.004
1280-1300	0.001
1300-1320	0.001
1320-1340	0.001
1340-1360	0.001

2.5.1.9.5 Mesoplodon bidens, Sowerby's Beaked Whale. Sowerby's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Sowerby's beaked whale occurs in the temperate North Atlantic Ocean, and its distribution overlaps congeners Gervais', Blainville's, and True's beaked whales (Carwardine, 1995). The habitat of Sowerby's beaked whale is poorly known, but visual observations were made in 550–1,500 m of water near Gully Canyon off the coast of Nova Scotia. Dive durations of whales in this habitat ranged from 12–28 min (Hooker and Baird, 1999b). Stomach content analysis of Sowerby's beaked whale revealed consumption of demersal, deep-dwelling fish, such as gadids (Santos et al., 1994; Santos et al., 1995). Gannon et al. (1998) reported that such fish are commonly found at depths of 400 m. Isotopic evaluation of the Sowerby's beaked whale diet suggested a large contribution of offshore vertically-migrating squid (Ostrom et al. 1993). Sowerby's and Blainville's beaked whales share similar diets (Mead, 1989; Herman et al., 1994; MacLeod et al., 2003a; Hickmott, 2005), therefore Sowerby's beaked whale will be modeled with a surrogate species, the Blainville's beaked whale, using the depth distribution provided in table 66.

Table 66. Percentage of Time at Depth for Sowerby's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.6 Mesoplodon carlhubbsi, Hubb's Beaked Whale. Hubb's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7).

Hubb's beaked whales are limited to the temperate North Pacific Ocean particularly along the North American coast from Southern California to British Columbia (Mead et al., 1982; Mead, 1989). Strandings have also been reported from Japan (Mead, 1989; Yamamoto et al., 2001). Prey species include pelagic squid and deep water fish species (Mead et al., 1982; Mead, 1989). Due to the limited information on foraging and diving behavior of this species, it will be represented by the depth distribution of its congener, the Blainville's beaked whale, provided in table 67

Table 67. Percentage of Time at Depth for Hubb's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-20	43.447
20-40	8.743
40-60	7.166
60-80	5.665
80-100	4.134
100-120	2.793
120-140	1.740
140-160	1.127
160-180	0.772
180-200	0.597
200-220	0.500
220-240	0.470
240-260	0.460
260-280	0.455
280-300	0.454
300-320	0.454
320-340	0.456
340-360	0.458
360-380	0.458
380-400	0.460
400-420	0.461
420-440	0.465
440-460	0.478
460-480	0.492
480-500	0.505
500-520	0.520
520-540	0.528
540-560	0.553
560-580	0.576
580-600	0.589
600-620	0.605
620-640	0.642
640-660	0.697
660-680	0.715
680-700	0.708
700-720	0.694
720-740	0.727
740-760	0.739
760-780	0.741
780-800	0.758
800-820	0.781
820-840	0.775
840-860	0.694
860-880	0.624
880-900	0.601
900-920	0.566
920-940	0.512
940-960	0.444
960-980	0.384
980-1000	0.330
1000-1020	0.285
1020-1040	0.228
1040-1060	0.182
1060-1080	0.146
1080-1100	0.110
1100-1120	0.078
1120-1140	0.057
1140-1160	0.048
1160-1180	0.050
1180-1200	0.045
1200-1220	0.030
1220-1240	0.015
1240-1260	0.004
1260-1280	0.004
1280-1300	0.001
1300-1320	0.001
1320-1340	0.001
1340-1360	0.001

2.5.1.9.7 Mesoplodon densirostris, Blainville's Beaked Whale. Blainville's beaked whale is a Tier 1 species. 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 includes mesopelagic cephalopods, fish, and crustaceans (Mead, 1989; Herman et al., 1994; MacLeod et al., 2003a; Hickmott, 2005). Values used to estimate Blainville's beaked whale movement and diving behavior as input into 3MB are provided in table 68.

Table 68. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for Blainville's Beaked Whale (Number Values Represent Mean (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Deep Foraging Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.5)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.79 (0.13)	Tyack et al. (2006)
	Descent Rate (m/s)	Gaussian 1.45 (0.2)	Tyack et al. (2006)
	Average Depth (m)	Gaussian 835 (143)	Tyack et al. (2006)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 20 (2)	Tyack et al. (2006)
	Probability of Reversal	0.95	Best estimate
	Reversal Dive Ascent Rate (m/s)	Gaussian 0.8 (0.2)	Madsen et al. (2005)
	Reversal Dive Descent Rate (m/s)	Gaussian 0.8 (0.2)	Madsen et al. (2005)
	Time in Reversal (s)	Gaussian 40 (20)	Tyack et al. (2006)
	Surface Interval (s)	Gaussian 228 (276)	Tyack et al. (2006)
	Bout duration	t=20. k=10	Best estimate
Shallow Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.5)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.35 (0.2)	Tyack et al. (2006) Baird et al. (2006)
	Descent Rate (m/s)	Gaussian 0.34 (0.2)	Tyack et al. (2006) Baird et al. (2006)
	Average Depth (m)	Gaussian 71 (52)	Tyack et al. (2006)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
General	Surface Interval (s)	Gaussian 228 (276)	Tyack et al. (2006)
	Bout duration	$t=_{20}$. k=10	Best estimate
	Depth limit on seeding (m)	633	Baird et al. (2006) Waring et al. (2001)
	Shore following (m)	633	Best estimate

The resulting depth distribution using the values in table 68 is provided in table 69. From this distribution, whales spent 59.4% of their time between 0–50 m, 21.6% of time between 20–80 m, and 16.8 % of time greater than 500 m in depth. In comparison with Baird et al. (2008b), these values are consistent with the reported values of 33.7–72.7% of their time spent at less than 50 m and 9.9–

39.4% of time spent between 22–72 m, and slightly less than the 18.3–37.4% of time spent at depths greater than 500 m. The maximum depth of the distribution is in agreement with a maximum depth of 1,251 m from Tyack et al. (2006) and slightly shallower than a depth of 1,408 m from Baird et al. (2006).

Table 69. Percentage of Time at Depth for the Blainville's Beaked Whale.

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.8 Mesoplodon europaeus, Gervais' Beaked Whale. Gervais' beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Gervais' beaked whale occurs in the North Atlantic Ocean, and appears to prefer deep water (Mead, 1989). Santos et al. (2007) reported that the stomach contents of an individual Gervais' beaked whale were similar to those of a Blainville's beaked whale. Both contained the remains of

Myctophid fishes and cephalopods. Myctophids are mesopelagic and bathypelagic species commonly found at depths greater than 1000 m, and the squid species have been found at depths ranging from 50–2000 m (Guerra Sierra, 1992). Many of the cephalopod species found in the diet of both whales appear to undergo daily vertical migrations, being found in shallower waters during the night and deeper waters during the day. Due to similarity in diet, Gervais' beaked whale will be modeled with a surrogate species, Blainville's beaked whale, using the depth distribution provided in table 70.

Table 70. Percentage of Time at Depth for Gervais' Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale.

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.9 Mesoplodon ginkgodens, Ginkgo-Toothed Beaked Whale. The ginkgo-toothed beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). These whales inhabit temperate and tropical waters of the North and South Pacific and Indian Oceans (Palacios, 1996). Ginkgo-toothed beaked whales have never been observed at sea, and, therefore, little is known about their diving or foraging behavior. Due to the paucity of data, the Ginkgo-toothed beaked whale will be represented by the depth distribution of the Blainville's beaked whale, also of the genus *Mesoplodon*, provided in table 71.

Table 71. Percentage of Time at Depth for the Ginkgo-Toothed Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.10 Mesoplodon mirus, True's Beaked Whale. True's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). True's beaked whale is found in the North Atlantic and in the Southern Hemisphere off the coast of South Africa and Australia (Culik, 2010). Its depth distribution is unknown but groups have been observed in 1,100-m water (Tove, 1995). Food habits for True's beaked whale are largely unknown, but are expected to be similar to other beaked whales in that they most probably consume vertically migrating squid and mesopelagic fishes associated with the deep scattering layer. Therefore, True's beaked whale will be modeled with a surrogate species, Blainville's beaked whale, using the depth distribution in table 72.

Table 72. Percentage of Time at Depth for True's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.11 Mesoplodon perrini, Perrin's Beaked Whale. Perrin's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Perrin's beaked whale is known from five stranded animals along central and southern California (Dalebout et al., 2002). Prey species include pelagic squid (Dalebout et al., 2002). Due to the paucity of data, Perrin's beaked whale will be represented by the depth distribution of Blainville's beaked whale, also of the genus *Mesoplodon*, provided in table 73.

Table 73. Percentage of Time at Depth for Perrin's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-20	43.447
20-40	8.743
40-60	7.166
60-80	5.665
80-100	4.134
100-120	2.793
120-140	1.740
140-160	1.127
160-180	0.772
180-200	0.597
200-220	0.500
220-240	0.470
240-260	0.460
260-280	0.455
280-300	0.454
300-320	0.454
320-340	0.456
340-360	0.458
360-380	0.458
380-400	0.460
400-420	0.461
420-440	0.465
440-460	0.478
460-480	0.492
480-500	0.505
500-520	0.520
520-540	0.528
540-560	0.553
560-580	0.576
580-600	0.589
600-620	0.605
620-640	0.642
640-660	0.697
660-680	0.715

Depth Bin (m)	Percentage of Time at Depth
680-700	0.708
700-720	0.694
720-740	0.727
740-760	0.739
760-780	0.741
780-800	0.758
800-820	0.781
820-840	0.775
840-860	0.694
860-880	0.624
880-900	0.601
900-920	0.566
920-940	0.512
940-960	0.444
960-980	0.384
980-1000	0.330
1000-1020	0.285
1020-1040	0.228
1040-1060	0.182
1060-1080	0.146
1080-1100	0.110
1100-1120	0.078
1120-1140	0.057
1140-1160	0.048
1160-1180	0.050
1180-1200	0.045
1200-1220	0.030
1220-1240	0.015
1240-1260	0.004
1260-1280	0.004
1280-1300	0.001
1300-1320	0.001
1320-1340	0.001
1340-1360	0.001

2.5.1.9.12 Mesoplodon peruvianus, Pygmy Beaked Whale. The pygmy beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Pygmy beaked whales are found in the Eastern Tropical Pacific, and strandings have been reported from Mexico to Chile (Reyes et al., 1991; Urbán-Ramírez and Aurioles-Gamboa, 1992; Wade and Gerrodette, 1993; Pitman, 2002b). Mesopelagic and benthic fish have been identified from stomach contents (Reyes et al., 1991). Due to the paucity of data, the pygmy beaked whale will be represented by the depth distribution of Blainville's beaked whale, also of the genus *Mesoplodon*, provided in table 74.

Table 74. Percentage of Time at Depth for the Pygmy Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-20	43.447
20-40	8.743
40-60	7.166
60-80	5.665
80-100	4.134
100-120	2.793
120-140	1.740
140-160	1.127
160-180	0.772
180-200	0.597
200-220	0.500
220-240	0.470
240-260	0.460
260-280	0.455
280-300	0.454
300-320	0.454
320-340	0.456
340-360	0.458
360-380	0.458
380-400	0.460
400-420	0.461
420-440	0.465
440-460	0.478
460-480	0.492
480-500	0.505
500-520	0.520
520-540	0.528
540-560	0.553
560-580	0.576
580-600	0.589
600-620	0.605
620-640	0.642
640-660	0.697
660-680	0.715

Depth Bin (m)	Percentage of Time at Depth
680-700	0.708
700-720	0.694
720-740	0.727
740-760	0.739
760-780	0.741
780-800	0.758
800-820	0.781
820-840	0.775
840-860	0.694
860-880	0.624
880-900	0.601
900-920	0.566
920-940	0.512
940-960	0.444
960-980	0.384
980-1000	0.330
1000-1020	0.285
1020-1040	0.228
1040-1060	0.182
1060-1080	0.146
1080-1100	0.110
1100-1120	0.078
1120-1140	0.057
1140-1160	0.048
1160-1180	0.050
1180-1200	0.045
1200-1220	0.030
1220-1240	0.015
1240-1260	0.004
1260-1280	0.004
1280-1300	0.001
1300-1320	0.001
1320-1340	0.001
1340-1360	0.001

2.5.1.9.13 Mesoplodon stejnegeri, Stejneger's Beaked Whale. Stejneger's beaked whale is a Tier 1 species that will be represented by a surrogate species, Blainville's beaked whale (section 2.5.1.9.7). Stejneger's beaked whales are found only in the temperate and subarctic waters of the North Pacific Ocean (Pitman, 2002b). At sea, animals have been sighted over the continental slope (Loughlin et al., 1982). Dive times of 10–15 min have been reported (Loughlin et al., 1982). Stomach contents analyses have indicated that primary prey species include various species of mesopelagic and bathypelagic squid (Loughlin and Perez, 1985; Walker and Hanson, 1999). Due to similarity in prey types, Stejneger's beaked whale will be represented by the depth distribution of Blainville's beaked whale, also of the genus *Mesoplodon*, provided in table 75.

Table 75. Percentage of Time at Depth for Stejneger's Beaked Whale, Based on Data from the Surrogate Species, Blainville's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth	Depth Bin (m)	Percentage of Time at Depth
0-20	43.447	680-700	0.708
20-40	8.743	700-720	0.694
40-60	7.166	720-740	0.727
60-80	5.665	740-760	0.739
80-100	4.134	760-780	0.741
100-120	2.793	780-800	0.758
120-140	1.740	800-820	0.781
140-160	1.127	820-840	0.775
160-180	0.772	840-860	0.694
180-200	0.597	860-880	0.624
200-220	0.500	880-900	0.601
220-240	0.470	900-920	0.566
240-260	0.460	920-940	0.512
260-280	0.455	940-960	0.444
280-300	0.454	960-980	0.384
300-320	0.454	980-1000	0.330
320-340	0.456	1000-1020	0.285
340-360	0.458	1020-1040	0.228
360-380	0.458	1040-1060	0.182
380-400	0.460	1060-1080	0.146
400-420	0.461	1080-1100	0.110
420-440	0.465	1100-1120	0.078
440-460	0.478	1120-1140	0.057
460-480	0.492	1140-1160	0.048
480-500	0.505	1160-1180	0.050
500-520	0.520	1180-1200	0.045
520-540	0.528	1200-1220	0.030
540-560	0.553	1220-1240	0.015
560-580	0.576	1240-1260	0.004
580-600	0.589	1260-1280	0.004
600-620	0.605	1280-1300	0.001
620-640	0.642	1300-1320	0.001
640-660	0.697	1320-1340	0.001
660-680	0.715	1340-1360	0.001

2.5.1.9.14 Ziphius cavirostris, Cuvier's Beaked Whale. Cuvier's beaked whale is a Tier 1 species. This species inhabits the deep waters of 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; Santos et al., 2001a; Hickmott, 2005). Values used to estimate Cuvier's beaked whale movement and diving behavior as input into 3MB are provided in table 76.

Table 76. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for Cuvier's Beaked Whale (Number Values Represent Mean (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Deep Foraging Dive	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.5)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.69 (0.19)	Tyack et al. (2006) Baird et al. (2006)
	Descent Rate (m/s)	Gaussian 1.47 (0.13)	Tyack et al. (2006) Baird et al. (2006)
	Average Depth (m)	Gaussian 1070 (317)	Tyack et al. (2006)
	Bottom Following	No	Best estimate
	Reversals	Gaussian 20 (2)	Tyack et al. (2006)
	Probability of Reversal	0.95	Best estimate
	Reversal Dive Ascent Rate (m/s)	Gaussian 0.8 (0.2)	Madsen et al. (2005)
	Time in Reversal	Gaussian 40 (20)	Tyack et al. (2006)
	Surface Interval (s)	Gaussian 474 (996)	Tyack et al. (2006)
	Bout duration	t=20 k=10	Best estimate
Shallow Dive	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	Gaussian 1.5 (0.5)	Best estimate
	Ascent Rate (m/s)	Gaussian 0.61 (0.2)	Tyack et al. (2006) Baird et al. (2006)
	Descent Rate (m/s)	Gaussian 0.53 (0.24)	Tyack et al. (2006) Baird et al. (2006)
	Average Depth (m)	Gaussian 221 (100)	Tyack et al. (2006)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 474 (996)	Tyack et al. (2006)
	Bout duration (s)	Gaussian 63 (31)	Tyack et al. (2006)
General	Depth limit on seeding (m)	1381	Baird et al. (2006) Waring et al. (2001)

The resulting depth distribution using the values in table 76 is provided in table 77. The distribution is consistent with foraging dives to 689-1888 m in the Ligurian Sea (Tyack et al., 2006) and 1450 m off Hawaii (Baird et al., 2006). From this distribution, whales spent 49.8% of their time between 0–50 m and 19.5 % of time greater than 500 m in depth. In comparison with Baird et al. (2008b), these values are within the range of reported values of 12.4–51.1% of their time spent at less than 50 m and less than the 33.9–52.1% of time spent at depths greater than 500 m. However, since animals are at highest risk of exposure in surface waters, the depth distribution in table 77 will stand as a conservative estimate.

Table 77. Percentage of Time at Depth for Cuvier's Beaked Whale

Depth Bin (m)	Percentage of Time at Depth
0-50	49.76
50-100	6.38
100-150	5.91
150-200	5.03
200-250	3.92
250-300	2.95
300-350	2.16
350-400	1.63
400-450	1.41
450-500	1.36
500-550	1.35
550-600	1.28
600-650	1.35
650-700	1.41
700-750	1.43
750-800	1.33
800-850	1.29
850-900	1.28
900-950	1.25
950-1000	1.13
1000-1050	1.07
1050-1100	0.93
1100-1150	0.8
1150-1200	0.74
1200-1250	0.61
1250-1300	0.49
1300-1350	0.41
1350-1400	0.29
1400-1450	0.21
1450-1500	0.22
1500-1550	0.18
1550-1600	0.15
1600-1650	0.09
1650-1700	0.07
1700-1750	0.05
1750-1800	0.03
1800-1850	0.01
1850-1900	0.01

2.5.2 Carnivores

2.5.2.1 Family Mustelidae

2.5.2.1.1 Enhydra lutris, Sea Otter. The sea otter is a Tier 2 species. Ranging around the North Pacific Ocean rim from Baja California, Mexico to the east coast of Kamchatka and the Kuril Islands, sea otters inhabit nearshore waters less than 60 m deep (Kenyon, 1981). Prey sources include benthic invertebrates (abalone, sea urchins, mussels, clams, snails, crabs, and worms) as well as the occasional bottom fish (Kenyon, 1981; Riedman and Estes, 1990; Laidre and Jameson, 2006).

Though sea otters have been studied extensively following their near extirpation by the fur trade, few studies have examined their diving capabilities. Early studies of dive behavior assumed average dives to be within 10–30 m (Kenyon, 1981), but one record reported recovery of a sea otter carcass from a crab pot set at 97 m (Newby, 1975). More recently, Bodkin et al. (2004) examined dive distributions of 14 foraging sea otters in Port Althorp, southeast Alaska from May through July. Activity budget analysis revealed that sea otters spent 37% of their time foraging (8.9 hrs/d), 11% diving/non-foraging (2.6 hr/d), and 52% resting (12.5 hr/d.; Bodkin et al., 2007), which is roughly consistent with activity budgets published for California sea otters (Yeates et al., 2007). Foraging dives averaged 18.9 m (SD = 4.6 m) while mean traveling dives were on average 2.7 m deep (SD = 0.2 m; Bodkin et al., 2004). Foraging and traveling dives also differed in descent (1.0 ± 0.04 m/s, 0.38 ± 0.02 m/s, respectively) and ascent rates (1.1 ± 0.06 m/s, 0.41 ± 0.04 m/s) and percent time on bottom (66 + 3 %, 27 + 3 %; Bodkin et al., 2004). Sea otters in this study completed a mean of 174 foraging dives per day (Bodkin et al., 2004). An observational study of sea otters off northern Washington state reported an average foraging dive time of 0.9 min consistent with Bodkin et al (2004), but a much greater maximum dive duration (5 min; Laidre and Jameson, 2006). Foraging dives could be segregated roughly into shallow and deep dives, and most foraging dives occurred in depths less than 20 m; however, a substantial amount of foraging also took place down to 60 m and five dives were recorded in excess of 90 m. 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). Pooling data from figure 2 of Bodkin et al. (2004) for shallow and deep dives, the average percent time spent at given depth bins for all 14 sea otters is shown in table 78.

Table 78. Percentage of Time at Depth for the Sea Otter

Depth Bin (m)	Percentage of Time at Depth		Depth Bin (m)	Percentage of Time at Depth
0-5	19		50-55	6
5-10	24		55-60	0.75
10-15	21		60-65	0.75
15-20	7		65-70	0.2
20-25	3		70-75	0.2
25-30	2		75-80	0.2
30-35	1		80-85	0.2
35-40	9		85-90	0.2
40-45	4		90-95	0.2
45-50	9		95-100	0.2

2.5.2.2 Family Otariidae

2.5.2.2.1 Arctocephalus townsendi, Guadalupe Fur Seal. The Guadalupe fur seal is a Tier 2 species that will be represented by a surrogate species, the Antarctic fur seal. Squid, teleost fish, and crustaceans comprise the diet of the Guadalupe fur seal (Riedman, 1990; Belcher and Lee, 2002; Aurioles-Gamboa and Camacho-Ríos, 2007). Information on the diving behavior of this species is mostly known from satellite tagging a single female following rehabilitation off southern California (Lander et al., 2000). Most dives were performed at night and lasted 2–4 min (mean dive time = 1.7 +1.0 min), with a maximum dive duration of 18 min (Lander et al., 2000). The maximum recorded dive depth was 130 m, although most dives were less than 20 m deep.

A recent taxonomic analysis reduced the Juan Fernandez fur seal and Guadalupe fur seal to conspecific subspecies (A. philippi philippi, and A. philippi townsendi, respectively; Brunner, 2004). The Juan Fernandez fur seal is the most closely related species, inhabiting similar off-shore island habitats, and sharing similar foraging and reproductive traits (Reeves et al., 2002), but little is known of its diving behavior. The diving behavior of the Antarctic fur seal is best studied of the Arctocephalids (Costa et al., 1989; Boyd and Croxall, 1992; Robinson et al., 2002) (Kooyman et al., 1986; Luque et al., 2007; Biuw et al., 2009), although its natural history differs dramatically from the Guadalupe fur seal, feeding on krill or penguins in some areas. The Antarctic fur seal also has a significantly shorter lactation period than that of the Guadalupe fur seal (4 versus 11 months).

Regional differences appear to be important in defining diving behavior in fur seals, as several studies have shown variation in prey selection, dive depths, and dive durations at different colonies of Antarctic and Subantarctic fur seals (Costa et al., 1989; Robinson et al., 2002; Luque et al., 2007; Biuw et al., 2009). Data on the Antarctic fur seal at MacQuarie Island best fits the feeding parameters and the known maximum dive capacity of the Guadalupe fur seal (Robinson et al., 2002). Percent time at depth is derived from figure 3 in Boyd and Croxall (1992) for 11 lactating female Antarctic fur seals feeding on mixed prey of MacQuarie Island, assuming 18.9% of the day is spent diving (table 79) (Kooyman et al., 1986; Boyd and Croxall, 1992).

Table 79. Percentage of Time at Depth for the Guadalupe Fur Seal Based on the Surrogate Species, the Antarctic Fur Seal

Depth Bin (m)	Percentage of Time at Depth		Depth Bin (m)	Percentage of Time at Depth
0-2	13		36-38	1.6
2-4	16		38-40	1.4
4-6	7		40-42	1.3
6-8	5		42-44	1.2
8-10	4.5		44-46	1.2
10-12	4		46-48	1.1
12-14	3.9		48-50	1.1
14-16	3.8		50-52	1.1
16-18	3.7		52-54	1
18-20	3.6		54-56	0.9
20-22	3.2		56-58	0.8
22-24	3		58-60	0.7
24-26	2.5		60-62	0.6
26-28	2.3		62-64	0.5
28-30	2.2		64-66	0.5
30-32	2.1		66-100	0.5
32-34	2		100-181	1
34-36	1.7			

2.5.2.2.2 Callorhinus ursinus, Northern Fur Seal. The northern fur seal is a Tier 2 species. Northern fur seals occupy the pelagic waters of the North Pacific Ocean, Bering Sea, and Sea of Japan, ranging coastally as far south as Baja California, Mexico, and Japan and with an at-sea southern limit around 35°N (Gelatt and Lowry, 2008). The diet of northern fur seals varies regionally and seasonally but is comprised principally of finfish (e.g., Pacific herring, sand lance, capelin, myctophids) and squid, and occasionally other prey such as birds and crustaceans (Riedman and Estes, 1990; Ream et al., 2005). Northern fur seals are known to feed in the deep waters of the continental shelf break, as well as shallower waters of the shelf itself (Ponganis et al., 1992; Gentry, 2002).

The dive behavior and physiology of the northern fur seal is well studied and it was among the earliest pinniped species to be tagged and tracked (Kooyman et al., 1976). Because northern fur seals spend the vast majority of their lives at sea (87–90% of year at sea) and only come ashore to breed for 35–45 days from June through August, most of the tagging studies examine the dive behavior of females on excursions from breeding colonies in the Bering Sea (Kooyman et al., 1976; Goebel et al., 1991; Baker and Donohue, 2000; Gentry, 2002; Ream et al., 2005; Baker, 2007; Kuhn et al., 2009).

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 potential 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%; Gentry et al., 1986). Individuals may be consistent in their choice of dive profile, presumably choosing different prey sources 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 profile type (Gentry et al., 1986; Hobson et al., 1997; Hobson and Sease, 1998; Gentry, 2002). 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 to dive to a maximum depth of 256 m (Ponganis et al., 1992), although they most frequently dive to 50–60 m and mean dive depth is 68 + 53 m (Gentry et al., 1986). Mean percent time spent at depth for four tagged female northern fur seals is shown in table 80 (table 1; Kooyman et al., 1976). Maximum recorded dive time for wild foraging females was 7 min (Gentry et al., 1986), though that measure was likely under anaerobic conditions as the aerobic dive limit for similarly sized seals (45 kg) is 3.7 min in captivity (Ponganis et al., 1992; Gentry, 2002). Dive bouts average 2.2 hr (132 min), with dives averaging 2.2 min and 35.7 dives per day. The activity budgets for adult females on foraging trips was 17% resting, 26% diving, and 57% surface active time (Gentry et al., 1986). Ponganis et al. (1992) measured swim velocities in two tagged adult females and found nearly identical ascent and descent rates, but significant differences when comparing deep versus shallow dives (deep: 1.625 m/s ± 0.31, shallow: 1.35 m/s ± 0.43).

Table 80. Percentage of Time at Depth for the Northern Fur Seal

Depth Bin (m)	Percentage 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

Male northern fur seal diving behavior has been examined recently (Sterling and Ream, 2004) and has revealed that like parturient females, juvenile males exhibit shallow versus deep dive patterns depending on foraging location (deep dives in water less than 200 m deep, shallow nighttime dives in water 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 + 1.5 m. Mean dive time was 1.24 + 0.09 min with a maximum dive time of 9.92 min (Sterling and Ream, 2004). Foraging areas utilized by juvenile male northern fur seals are similar to those of parturient females; however, males tend to spend longer durations at sea and show differential dive densities and spatial distributions that may relieve competition during the breeding season (Sterling and Ream, 2004).

2.5.2.2.3 Eumetopias jubatus, Steller Sea Lion. The Steller sea lion is a Tier 2 species. Steller sea lions inhabit the Pacific Ocean north of approximately 30° N latitude (Schusterman, 1981; Loughlin 2002). 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 81.

Table 81. 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 81 will be used as a proxy for depth distribution data. Rehberg et al. (2009) reported that on average females spent 22.1% of their time at sea submerged. Therefore, the distribution in table 81 should be adjusted to represent 22.1% of an animal's time, with 77.9% 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 was adjusted to reflect this. The resulting depth distribution is given in table 82.

Table 82. Percentage of Time at Depth for the Steller Sea Lion

Depth Bin (m)	Percentage 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

The depth distribution in table 82 is consistent with research suggesting most dives are within the top 50 m (Merrick et al., 1994; Merrick and Loughlin, 1997; Loughlin et al., 1998; Loughlin et al., 2003; Fadely et al., 2005). 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 et al., 1994; Merrick and Loughlin, 1997), although in both seasons the majority of dives are shallow (< 50 m).

2.5.2.2.4 Zalophus californianus, California Sea Lion. The California sea lion is a Tier 1 species. California sea lions primarily breed on island beaches off southern California, Baja Mexico, and in the Gulf of California (Heath, 2002). They 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 dive shallowly in some coastal areas for epipelagic prey, and more deeply in others, such as the Gulf of California, for mesopelagic prey (Lowry and Carretta, 1999; Melin and DeLong, 1999; Costa et al., 2004). Values used to estimate California sea lion movement and diving behavior as input into 3MB are given in table 83. Data indicate differences in diving behavior of male (Weise, 2006) and female (Kuhn, 2006) sea lions. Therefore, separate profiles were created for each sex. To create the depth distribution, a simulation was run as described in section 2.2.2.2; however, 50 animals of each sex were included, rather than the 100 animals described. The results were averaged to create a depth distribution for the species.

Table 83. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the California Sea Lion (Number Values Represent Mean (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Diving	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 0.84 (0.1)	Kuhn (2006)
	Ascent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Descent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Average Depth (m)	Female: Gaussian 58.2 (8.4) Male Day: Gaussian 35.3 (1.3) Male Night: Gaussian 28.4 (1.1)	Kuhn (2006) Weise (2006) Weise (2006)

Table 83. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the California Sea Lion (Number Values Represent Mean (SD) Unless Otherwise Indicated) (Cont'd)

Behavior	Variable	Value	Reference
Diving (Cont'd)	Bottom Following	Yes	Best estimate
	Reversals	Gaussian 21 (3)	Best estimate
	Probability of Reversal	0.8	Best estimate
	Reversal Dive Ascent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Reversal Dive Descent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Time in Reversal (s)	Gaussian 2 (0.1)	Kuhn (2006)
	Surface Interval (s)	Female: Gaussian 360 (48) Male Day: Gaussian 87.3 (2.3) Male Night: Gaussian 93.7 (2.3)	Kuhn (2006) Weise (2006) Weise (2006)
	Bout duration (s)	Gaussian 198 (90)	Feldkamp et al. (1989)
Surface and Sub-Surface Transit	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 0.84 (0.1)	Kuhn (2006)
	Ascent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Descent Rate (m/s)	Female: Gaussian 1.20 (0.3) Male: Gaussian 1.0 (0.4)	Kuhn (2006) Weise (2006)
	Average Depth (m)	Female: Uniform max = 4 Male: Uniform max= 5.5	Kuhn (2006) Weise (2006)
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 10 (3)	Best estimate
	Bout duration (s)	Gaussian 132 (186)	Feldkamp et al. (1989)
Resting	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	10	Best estimate
	Termination Coefficient	0.2	Best estimate
	Travel Rate (m/s)	Gaussian 0 (0)	Best estimate
	Ascent Rate (m/s)	Uniform max = 0.1	Best estimate
	Descent Rate (m/s)	Uniform max = 0.1	Best estimate
	Average Depth (m)	Uniform max = 0.5	Best estimate
	Bottom Following	No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 10 (3)	Best estimate
	Bout duration (s)	Gaussian 24 (42)	Feldkamp et al. (1989)
General	Depth limit on seeding (m)	2.1	Best estimate
	Shore following (m)	2.1	Best estimate

The resulting depth distribution using the values in table 83 is provided in table 84. The depth distribution is shallower than the maximum diving depths reported for the species (400–575 m; Kuhn, 2004; Melin et al., 2008). It also does not capture the maximum dive depths reported from females in several locations (> 200 m; Feldkamp et al., 1989; Costa et al., 2004). However, the depth distribution in table 84 is consistent with studies by Kuhn (2004) and Weise et al. (2006), who demonstrated that the majority of dives for both males and females were less than 50-m deep. Similarly, Melin and DeLong (1999) and Feldcamp (1989) reported that most dives were shallower than 100 m. Therefore, although the depth distribution in table 84 may be shallower than seen in some locations, it does capture published diving behavior for the species, and is representative for California sea lions.

Table 84. Percentage of Time at Depth for the California Sea Lion

Depth Bin (m)	Percentage of Time at Depth
0-10	84.87
10-20	2.89
20-30	3.85
30-40	4.40
40-50	1.46
50-60	1.45
60-70	0.87
70-80	0.20
80-90	0.01

2.5.2.3 Family Phocidae

2.5.2.3.1 Cystophora *cristata, Hooded Seal.* The hooded seal is a Tier 2 species. Hooded seals typically inhabit continental shelf and slope waters of the North Atlantic Ocean. Adults feed on commercial-size fish such as capelin, cod, and redfish, as well as squid and amphipods (Hauksson and Bogason, 1997; Bjørke, 2001; Haug et al., 2004). Folkow and Blix (1999) reported an average percentage of dive depths in five depth bin categories, as well as an average estimated submersion time (77%), for 16 seals from the Greenland Sea (table 85). While not an estimate of time spent at depth, it is the closest approximation to a depth distribution in the published literature. The dive depths are consistent with those reported by Bajzak et al. (2009) for post-breeding seals, although the seals dived to shallower depths during the molting period. Seals from the Gulf of St. Lawrence spent similar percentage of their time diving, but considerably less during the molting period (Bajzak et al., 2009). However, the depth distribution in table 85 represents dive depths from seals in waters of different depths; therefore, this depth distribution represents a reasonable average.

Table 85. Percentage of Time at Depth for the Hooded Seal

Depth Bin (m)	Percentage of Time at Depth
0-1	23
1-52	13.09
52-100	6.16
100-600	54.67
600-968	1.925
968-1016	1.155

2.5.2.3.2 Erignathus barbatus, Bearded Seal. The bearded seal is a Tier 2 species. Bearded seals have a circumpolar distribution, and follow the advancement and retreat of the polar ice cap during seasonal migrations (Antonelis et al., 1994). Bearded seals are often found further offshore than the sympatric ringed seal (Bengston et al., 2005). They are generalist feeders, consuming both pelagic and demersal fish, as well as epifaunal and infaunal invertebrates. Their main prey includes fish such as polar cod and capelin, crabs, shrimp, and mollusks (Lowry et al., 1980; Antonelis et al., 1994; Hjelset et al., 1999). Bearded seals are considered shallow divers, with most dives to less than 100 m (Kingsley et al., 1985). Gjertz et al. (2000b) reported diving behavior of adult females and their pups in shallow, coastal regions around Svalbard, Norway. Visual inspection of figure 4 in Gjertz et al. (2000b) provided an estimate of percentage of dives to varying depths provided in table 86. While this is a record of number of dives to a particular depth rather than a distribution of time spent at a particular depth, it is the best estimate available in the literature to date.

Table 86. Dive Depth Data from Gjertz et al. (2000b) Used to Estimate Depth Distribution for the Bearded Seal

Dive Bin (m)	Percentage of Dives				
	Seal ID				
	2040	2068	2084	2089	Average
2-10	12.32	28.71	43.15	66.33	37.63
10-20	2.46	5.94	6.09	26.13	10.16
20-30	0.49	10.89	1.02	2.01	3.60
30-40	6.90	14.85	2.54	2.01	6.57
40-50	15.76	10.89	12.69	1.01	10.09
50-60	22.17	13.86	11.17	2.01	12.30
60-70	23.15	7.43	7.61	0.50	9.67
70-80	10.84	2.48	2.03	0	3.84
80-90	4.93	2.48	3.05	0	2.61
90-100	0.99	0.99	2.54	0	1.13
100-150	0	1.49	7.61	0	2.27
150-200	0	0	0.51	0	0.13
200-250	0	0	0	0	0
>250	0	0	0	0	0

Krafft et al. (2000) placed satellite time depth recorders on lactating seals in the same region and reported an activity budget for these seals. Visual inspection of their figure 1 provides estimates of time hauled out, in the water at the surface, and diving that is provided in table 87.

Table 87. Activity Budget Data from Krafft et al. (2000) Used to Estimate Time at the Surface for the Bearded Seal

Behavior	Percentage of Time				
	Seal ID				Average
	E4259	E4269	E4363	E4399	
Diving	46.5	44	46	53	47.375
Surface	48.5	47	48	34	44.375
Hauled out	5	9	6	13	8.25

When the percentage of time diving and at the surface are recalculated as a percentage of time in the water, female seals spent 48.37% of their time at the surface. When the average depth distribution from table 86 is multiplied by the percentage of time that animals spent diving (51.63%), the depth distribution in table 88 results. The caveat to using this depth distribution is that it is derived from nursing females, which spend some period of time floating near the ice edge while their pups are hauled out (Krafft et al., 2000). However, the observations are consistent with those of Kingsley et al. (1985), who reported that bearded seals primarily make use of the top 100 m of the water column. From table 86, less than 3% of dives on average are below 100 m. The maximum dive depth reported was to 472 m; however, dives to such depths were a negligible portion of the total dives. Therefore, the depth distribution in table 88 represents a reasonable estimate of the percentage of time spent in various depth bins.

Table 88. Percentage of Time at Depth for the Bearded Seal

Depth Bin (m)	Percentage of Time at Depth
0-2	48.37
2-10	19.43
10-20	5.24
20-30	1.86
30-40	3.39
40-50	5.21
50-60	6.35
60-70	5.00
70-80	1.98
80-90	1.35
90-100	0.58
100-150	1.17
150-200	0.07

2.5.2.3.3 Halichoerus grypus, Grey Seal. The grey seal is a Tier 2 species. Grey seals are found in temperate, coastal waters of the North Atlantic Ocean. They feed on both pelagic (herring and sand lance) and benthic (flatfish) prey (Bowen et al., 1993; Iverson et al., 2004). Seals spend the largest period of time hauled out in the winter for breeding and in the spring for molting. Harvey et al. (2008) presented a distribution of maximum dive depths given in table 89 for a range of age, sex, and seasonal classes. While this is not a depth distribution in terms of time spent at depth, it does represent the consensus that grey seals are relatively shallow divers (Thompson et al., 1991;

McConnell et al., 1999; Sjoberg and Ball, 2000; Lidgard et al., 2003). Beck et al. (2003) reported that 73.9% and 59.4% of dives were in the top 60 m during the day and night, respectively, and that 95.9% of dives were in the top 120 m. Lidgard et al. (2003) found that 41% of dives were within 10 m of the surface. Grey seals are capable of dives to 354 m (females) and 412 m (males) (Beck et al., 2003).

Table 89. Dive Depth Data from Harvey et al. (2008) Used to Estimate Depth Distribution for the Grey Seal

Maximum dive depth (m)	Percentage of dives
0-40	79
40-100	17
100-200	4
>200	1

The data from in table 89 only consider when the animal is beneath the surface. Thompson et al. (1991) tracked three swimming juvenile grey seals and reported that across three behavioral states, animals spent on average 84.1% of their time submerged (table 90).

Table 90. Percentage of Time Submerged from Thompson et al. (1991) Used to Estimate Depth Distribution for the Grey Seal

Behavior	Percentage of Time Submerged
Traveling	84.3
Short duration trips	83.5
Resting (all)	84.5
Average	84.1

While most studies give some indication of proportion of time spent diving, they generally include time spent hauled out on land in the total duration. Therefore, the average time spent at the surface from Thompson et al. (1991) will be combined with the dive distribution data from Harvey et al. (2008) to generate an estimate of the depth distribution for the grey seal (table 91). The maximum dive depth of 412 m reported by Beck et al. (2003) is used as the maximum depth in table 91.

Table 91. Percentage of Time at Depth for the Grey Seal

Depth Bin (m)	Percentage of Time at Depth
0-1	15.9
1-40	65.8
40-100	14.2
100-200	3.3
200-412	0.8

2.5.2.3.4 Mirounga angustirostris, Northern Elephant Seal. The northern elephant seal is a Tier 1 species. 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 south to Baja California, 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 eat a variety of prey species, including elasmobranchs, crustaceans, cephalopods and fish (DeLong and Stewart, 1991; Stewart and Huber, 1993; Sinclair, 1994). Due to sex differences in foraging behavior (Le Boeuf et al., 1993), diving behavior was categorized separately for each sex. To generate a depth distribution, 50 females and 50 males were input into 3MB to represent the 100 animals in the simulated population (section 2.2.2.2). Values used to estimate female and male Northern elephant seal movement and diving behavior as input into 3MB are provided in table 92.

Table 92. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Northern Elephant Seal (Number Values Represent Mean (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Type A dives	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	5	Best estimate
	Termination Coefficient	2	Best estimate
	Travel Rate (m/s)	Female: Gaussian 1.65 (0.44) Male: Gaussian 1.75 (0.27)	Hassrick et al. (2007)
	Ascent Rate (m/s)	Female: Gaussian 0.92 (0.23) Male: Gaussian 0.57 (0.23)	Hassrick et al. (2007)
	Descent Rate (m/s)	Female: Gaussian 1.03 (0.31) Male: Gaussian 0.55 (0.21)	Hassrick et al. (2007)
	Average Depth (m)	Female: Gaussian 509 (147) Male: Gaussian 380.5 (142.3)	Le Boeuf et al. (1993) Hassrick (2004)
	Bottom Following	Female: Yes Male: No	Best estimate
	Reversals	No	Best estimate
	Surface Interval (s)	Female: Gaussian 124.8 (28.2) Male: Gaussian 180 (258)	Le Boeuf et al. (1993) Hassrick (2004)
	Bout duration (s)	Female: Gaussian 571.4 (289.8) Male: Gaussian 771.3 (223.6)	Hassrick et al. (2007) Hassrick (2004)
Type D dives	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	Female: 10 Male: 5	Best estimate
	Termination Coefficient	2	Best estimate
	Travel Rate (m/s)	Female: Gaussian 1.47 (0.33) Male: Gaussian 1.72 (0.33)	Hassrick et al. (2007)
	Ascent Rate (m/s)	Female: Gaussian 1.20 (0.16) Male: Gaussian 0.91 (0.23)	Hassrick et al. (2007)
	Descent Rate (m/s)	Female: Gaussian 1.37 (0.25) Male: Gaussian 0.91 (0.23)	Hassrick et al. (2007)
	Average Depth (m)	Female: Gaussian 545 (33) Male: Gaussian 362.3 (115.1)	Le Boeuf et al. (1993) Hassrick et al. (2007)
	Bottom Following (m)	Female: Yes Male: No	Best estimate

Table 92. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Northern Elephant Seal (Number Values Represent Mean (SD) Unless Otherwise Indicated) (Cont'd)

Behavior	Variable	Value	Reference
Type D dives (Cont'd)	Reversals	Gaussian 2.4 (0.7)	Le Boeuf et al. (2000)
	Probability of Reversal	1.00	Best estimate
	Reversal Dive Ascent Rate (m/s)	Female: Gaussian 1.20 (0.16) Male: Gaussian 0.91 (0.23)	Hassrick et al. (2007)
	Reversal Dive Descent Rate (m/s)	Female: Gaussian 1.37 (0.25) Male: Gaussian 0.91 (0.23)	Hassrick et al. (2007)
	Time in Reversal (s)	Gaussian 14.2 (9.9)	Le Boeuf et al. (2000), Hassrick et al. (2007)
	Surface Interval (s)	Female: Gaussian 124.8 (28.2) Male: Gaussian 162 (48)	Le Boeuf et al. (1993)
	Bout duration (s)	Gaussian 1192.8 (662)	Hassrick (2004)
Type E dives: Males only	Travel Direction	Correlated random walk	Best estimate
	Perturbation value	5	Best estimate
	Termination Coefficient	2	Best estimate
	Travel Rate (m/s)	Gaussian 1.64 (0.4)	Hassrick et al. (2007)
	Ascent Rate (m/s)	Gaussian 1.00 (0.29)	Hassrick et al. (2007)
	Descent Rate (m/s)	Gaussian 1.05 (0.29)	Hassrick et al. (2007)
	Average Depth (m)	Gaussian 370.5 (290.6)	Hassrick (2004)
	Bottom Following	Yes	Best estimate
	Bottom Following Travel Rate	Gaussian 1.29 (0.53)	Hassrick et al. (2007)
	Reversals	No	Best estimate
	Surface Interval	Gaussian 192 (300)	Hassrick (2004)
	Bout duration	Gaussian 1342.7 (324.3)	Hassrick (2004)
General	Depth limit on seeding (m)	Max	Best estimate
	Shore following (m)	2.1	Best estimate

Table 93 gives the depth distribution for adult Northern elephant seals based on the input data given in table 92. Le Boeuf et al. (1988) reported that dives to deeper than 700 m were rare for female elephant seals, and the percentage of time at depth shallower than 700 m accounts for 98.81% of the depth distribution in table 93. Le Boeuf et al. (1989) reported that 0.42% of all dives were to deeper than 800 m, and these depths account for 0.46% of the current distribution. The maximum dive depth is in agreement with the maximum dive depth of 1250 m measured by Le Boeuf et al. (1989), shallower than reported dives to 1380 m and 1529 m (DeLong and Stewart, 1991; Le Boeuf et al., 2000), and deeper than maximum dives to 430 m , 780 m, 800 m, and 894 m reported by Davis et al., (2001), Crocker et al. (2006), Davis and Weihs (2007), and Le Boeuf et al. (1988).

Table 93. Percentage of Time at Depth for the Northern Elephant Seal

Dive Depth (m)	Percentage of Time at Depth	Dive Depth (m)	Percentage of Time at Depth
0-50	30.35	650-700	0.75
50-100	9.12	700-750	0.46
100-150	8.38	750-800	0.29
150-200	7.90	800-850	0.18
200-250	7.44	850-900	0.11
250-300	6.99	900-950	0.07
300-350	6.44	950-1000	0.04
350-400	5.70	1000-1050	0.03
400-450	4.92	1050-1100	0.02
450-500	4.14	1100-1150	0.01
500-550	3.33	1150-1200	0.002
550-600	2.15	1200-1250	0.001
600-650	1.20		

2.5.2.3.5 Monachus schauinslandi, Hawaiian Monk Seal. The Hawaiian monk seal is a Tier 2 species. The range of the Hawaiian monk seal is limited to the central Pacific with breeding colonies principally in the northwestern Hawaiian Islands (Gilmartin and Forcada, 2002; Johanos and Baker, 2002). Hawaiian monk seals primarily consume benthic prey, and stomach contents and scat analyses indicate that prey constitute both diurnal and nocturnal species. Reef associated fish and octopus compose a large portion of the diet (Kenyon and Rice, 1959; DeLong et al., 1984; Goodman-Lowe, 1998). Most seals focus foraging effort in the top 100 m of the water column, although some seals dive to greater than 300 m (Parrish et al., 2000; Parrish et al., 2002; Parrish et al., 2005; Stewart et al., 2006). Stewart and Yochem (2004a, b) presented depth distributions for 18 animals from Kure Atoll and Laysan Island, respectively. Visual inspection of figure 26 from Stewart and Yochem (2004a) and figure 41 from Stewart and Yochem (2004b) resulted in the depth distribution in table 94. Due to the even distribution of males and females, the data were averaged to create a general species depth distribution. The maximum dive depth reported was greater than 490 m; therefore, 500 m is used as a conservative maximum dive depth.

Table 94. Percentage of Time at Depth for the Hawaiian Monk Seal

Depth Bin (m)	Percentage of Time at Depth				
	Stewart and Yochem (2004a)		Stewart and Yochem (2004b)		Average
	Females (4)	Males (4)	Females (5)	Males (5)	
0-4	41	32	26.5	32.5	33.0
4-20	53.7	31	22.5	31.5	34.7
20-40	1.8	10	24.5	16.5	13.2
40-60	1.3	5	6.5	9	5.5
60-80	1.8	5	3.5	4	3.6
80-100	0.3	4	1.5	2.5	2.1
100-120	0.1	5	4	1	2.5
120-140	0	2	5	1	2.0
140-160	0	0.5	1.5	1	0.8
160-180	0	1.5	0.75	0.5	0.7
180-200	0	1	0	0	0.3
200-250	0	0.5	1	0	0.4
250-350	0	1	2.5	0	0.9
350-500	0	1.5	0.25	0.5	0.6

In the above depth distribution, 92% of the time is spent within the top 100 m. This is consistent with previous studies, demonstrating foraging occurring at shallow reef sites (DeLong et al., 1984; Schlexer, 1984; Parrish et al., 2000; Littnan et al., 2004).

2.5.2.3.6 Pagophilus groenlandicus, Harp Seal. The harp seal is a Tier 2 species. Harp seals are found in ice-associated waters of the Arctic (Lavigne, 2002). Harp seals forage on a variety of prey, including Arctic cod and capelin, amphipods, and krill (Lawson et al., 1998; Nilssen et al., 2001; Haug et al., 2004). Folkow et al. (2004) characterized diving behavior of 16 adult harp seals in two different years. While close to the ice edge during the breeding and molting season in summer, seals spent most of their time in shallow depths, with 70–90% of their diving time spent in the top 50 m of the water column (Folkow et al., 2004). Based on visual inspection of figure 5A in Folkow et al. (2004), the depth distributions for seals during the post breeding to post molting period are given in table 95. These data are consistent with Lyderson and Kovacs (1993), which found that lactating females had maximum dive depths of 90 m.

Table 95. Depth Distribution Data from Folkow et al. (2004) for Harp Seals During the Breeding and Molting Season (Numbers in Parentheses Indicate the Number of Seals Averaged for Each Depth Distribution)

Depth Bin (m)	Percentage of Time at Depth				
	June		July		
	Denmark Strait (3)	Greenland Sea (10)	Greenland Sea (9)	Barents Sea (6)	Average
0-20	54	66	51	36	51.75
20-50	36	27	26	28	29.25
50-100	9	6	12	21	12
100-200	1	1	8	11	5.25
200-300	0	0	3	4	1.75
300-400	0	0	0	0	0
400-492	0	0	0	0	0

Folkow et al. (2004) reported that after this period of time close to the ice edge, the seals then moved into deeper water in the open ocean, diving up to 498 m and 562 m in the different years. Table 96 gives the average yearly percentage of time hauled out and diving to depth for harp seals from the Greenland Sea based on visual inspection of figure 7C of Folkow et al. (2004). Pacific cod, one of the dominant prey types found in seals feeding offshore, inhabit the top 300 m of the water column consistent with the diving depths in table 96 (Wathne et al., 2000).

Table 96. Average Percent of Time Hauled Out and Diving Depth Distribution Data from Folkow et al. (2004) for Harp Seals

Depth Bin (m)	Percentage of Time at Depth
Out of water	7.5
0-20	29.5
20-50	15.5
50-100	15
100-200	17
200-300	10
300-400	4.5
400-492	1

Given the characteristic shallow diving pattern in the post-breeding to post-molting period, two depth distributions are given in table 97 for the harp seal.

Table 97. Percentage of Time at Depth for the Harp Seal

Depth Bin (m)	Percentage of Time at Depth	
	Post-breeding to Post-molting	Remainder of Year
0-20	51.75	31.89
20-50	29.25	16.76
50-100	12	16.22
100-200	5.25	18.38
200-300	1.75	10.81
300-400	0	4.86
400-492	0	1.08

2.5.2.3.7 Phoca vitulina, Harbor Seal. The harbor seal is a Tier 1 species. 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; Payne and Selzer, 1989; Olesiuk, 1993). Values used to estimate harbor seal movement and diving behavior as input into 3MB are provided in table 98.

Table 98. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Harbor Seal (Number Values Represent Mean (SD) Unless Otherwise Indicated)

Behavior	Variable	Value	Reference
Dive type 0 (< 4 m)	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	0.37 (0.39)	Lesage et al. (1999)
	Ascent Rate (m/s)	Gaussian 0.71 (0.46)	Lesage et al. (1999)
	Descent Rate (m/s)	Gaussian 0.76 (0.47)	Lesage et al. (1999)
	Average Depth (m)	Gaussian 2.0 (1.0))	Lesage et al. (1999)
	Bottom Following	No	Lesage et al. (1999)
	Reversals	No	Best estimate
	Surface Interval (s)	Gaussian 10 (2)	Best estimate
Dive type 1	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	0.48 (0.32)	Lesage et al. (1999)
	Ascent Rate (m/s)	Gaussian 1.13 (0.16)	Lesage et al. (1999)
	Descent Rate (m/s)	Gaussian 1.12 (0.19)	Lesage et al. (1999)
	Average Depth (m)	Gaussian 76.51 (21.14)	Lesage et al. (1999)
	Bottom Following	Gaussian 1.0 (0.47)	Lesage et al. (1999)
	Reversals	Gaussian 5.0 (2.0)	Lesage et al. (1999)
	Probability of Reversal	0.08	Lesage et al. (1999)
	Time in Reversal (s)	Gaussian 5.0 (1.0)	Lesage et al. (1999)
	Surface Interval (s)	Gaussian 42.6 (23.5)	Lesage et al. (1999)
Dive type 2	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	0.37 (0.39)	Lesage et al. (1999)
	Ascent Rate (m/s)	0.61 (0.25)	Lesage et al. (1999)
	Descent Rate (m/s)	0.66 (0.27)	Lesage et al. (1999)
	Average Depth (m)	12.2 (9.07)	Lesage et al. (1999)
	Bottom Following	No	Lesage et al. (1999)

Table 98. Data Values and Source References for Inputs into 3MB Software to Create Depth Distribution Data for the Harbor Seal (Number Values Represent Mean (SD) Unless Otherwise Indicated) (Cont'd)

Behavior	Variable	Value	Reference
Dive type 2 (Cont'd)	Reversals	No	Best estimate
	Surface Interval (s)	43.8 (60.7)	Lesage et al. (1999)
Dive type 3	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	0.89 (0.42)	Lesage et al. (1999)
	Ascent Rate (m/s)	0.85 (0.23)	Lesage et al. (1999)
	Descent Rate (m/s)	0.64 (0.25)	Lesage et al. (1999)
	Average Depth (m)	51.85 (21.56)	Lesage et al. (1999)
	Bottom Following	1.21 (0.44)	Lesage et al. (1999)
	Reversals	Gaussian 5.0 (0.2)	Best estimate
	Probability of Reversal	0.08	Lesage et al. (1999)
	Time in Reversal (s)	Gaussian 5.0 (1.0)	Best estimate
	Surface Interval (s)	Gaussian 40.2 (31.0)	Lesage et al. (1999)
Dive type 4	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	Gaussian 0.50 (0.32)	Lesage et al. (1999)
	Ascent Rate (m/s)	Gaussian 0.38 (0.18)	Lesage et al. (1999)
	Descent Rate (m/s)	Gaussian 0.76 (0.19)	Lesage et al. (1999)
	Average Depth (m)	Gaussian 27.27 (10.14)	Lesage et al. (1999)
	Bottom Following	Gaussian 0.68 (0.40)	Lesage et al. (1999)
	Reversals	Gaussian 5.0 (0.2)	Best estimate
	Probability of Reversal	0.08	Lesage et al. (1999)
	Time in Reversal (s)	Gaussian 5.0 (1.0)	Best estimate
	Surface Interval (s)	Gaussian 38.6 (34.8)	Lesage et al. (1999)
Dive type 5	Travel Direction	Correlated random walk	Best estimate
	Travel Rate (m/s)	Gaussian 0.21 (0.31)	Lesage et al. (1999)
	Ascent Rate (m/s)	Correlated random walk	Best estimate
	Descent Rate (m/s)	Gaussian 0.70 (0.17)	Lesage et al. (1999)
	Average Depth (m)	Gaussian 65.14 (31.07)	Lesage et al. (1999)
	Bottom Following	Gaussian 0.15 (0.25)	Lesage et al. (1999)
	Reversals	Gaussian 0.50 (2.0)	Best estimate
	Probability of Reversal	0.08	Lesage et al. (1999)
	Time in Reversal (s)	Gaussian 5.0 (1.0)	Best estimate
	Surface Interval (s)	Gaussian 44.8 (31.9)	Lesage et al. (1999)
General	Depth limit on Seeding (m)	<250	Lowry et al. (2001) Gjertz et al. (2001) Lander et al. (2002)
	Shore Following (m)	2.1	Best estimate

The resulting depth distribution using the values in table 98 is provided in table 99. The depth distribution range covers dives to 14–59 m off Nova Scotia (Bowen et al., 1999) and 20–100 m in Prince William Sound (Frost et al., 2001). Fifty to ninety percent of dives by individual seals in another study in Prince William Sound were to 4–50 m, and dives to greater than 100 m accounted for less than 6% of all dives, 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% of dives were shallower than 40 m, and 95% were to less than 250 m (Gjertz et al., 2001). Eguchi and Harvey (2005) found that males dive deeper than females, with 95% of dives shallower than 154 m and 76 m for males and females, respectively. Therefore, the depth distribution in table 99 is a reasonable estimate of time spent at depth for all populations of harbor seals.

Table 99. Percentage of Time at Depth for the Harbor Seal

Depth Bin (m)	Percentage of Time at Depth
0-15	72.94
15-30	9.51
30-45	6.55
45-60	4.68
60-75	3.25
75-90	1.85
90-105	0.83
105-120	0.28
120-135	0.08
135-150	0.02
150-165	0.01
165-180	0.00

2.5.2.3.8 Pusa hispida, Ringed Seal. The ringed seal is a Tier 2 species. Ringed seals have a circumpolar distribution within Arctic waters. Primary prey species include arctic cod, amphipods, and crustaceans (Wathne et al., 2000; Labansen et al., 2007). Seals spend extended time hauled out on the ice during breeding and molting periods, otherwise the majority of time making extended foraging trips at sea. Lydersen (1991) reported the percentage of dives in different depth bins, as well as the percentage of time while in the water submerged versus at the surface (30.3%). If the percentage of dives in different depth bins are used as a proxy for percentage of time spent in the bins, the depth distribution in table 100 results. These data are from a single female ringed seal over a 6-day period.

Table 100. Percentage of Time at the Surface and in Different Depth Bins from Lydersen (1991) for the Ringed Seal

Depth Bin (m)	Percentage of Time at Depth
surface	30.30
0-5	27.88
5-10	13.94
10-15	11.85
15-20	6.27
20-25	1.39
25-30	4.18
30-35	2.79
35-40	1.39

Gjertz et al. (2000a) reported the percentage of dives to different depths for 16 ringed seals carrying tags between 1 and 8 months. If the percentage of time at the surface from Lydersen (1991) is used as an estimate, and the percentage of dives taken as a proxy for the percentage of time, then the depth distribution from table 101 results. Theses dive depths are consistent with Wathne et al. (2000), who found that ringed seals feed on shallower prey than harp seals (section 2.5.2.3.5), which make 35% of their dives to deeper than 100 m, and with Gjertz et al. (2000a) who found that 90% of dives by harbor seals were shallower than 100 m.

Table 101. Percentage of Time at Depth for the Ringed Seal

Depth Bin (m)	Percentage of Time at Depth
0-1	30.3
1-4	9.76
4-8	13.24
8-12	5.23
12-16	3.49
16-20	1.39
20-30	5.58

Depth Bin (m)	Percentage of Time at Depth
30-40	4.88
40-50	4.18
50-100	14.64
100-150	5.58
150-200	1.39
200-300	0.35

2.5.3 Sirenians

2.5.3.1 Family Trichechidae

2.5.3.1.1 Trichechus manatus, West Indian Manatee. The West Indian manatee is a Tier 2 species. The West Indian manatee is found in coastal and estuarine waters of the mid-Atlantic United States south through the waters of central Brazil (Reynolds III and Powell 2002). Manatees are primarily herbivores feeding on plants in all parts of the water column (Baugh et al., 1989; Lefebvre et al., 2000; Alves-Stanley et al., 2010). There are occasional reports of manatees feeding on fish and invertebrate prey (Etheridge et al., 1985; O'Shea et al., 1991; Courbis and Worthy, 2003). Manatees are limited to shallow water (less than 20 m), due to the light requirements of the vegetation on which they feed (Wells et al., 1999). Nowacek at al. (2002) reported the percent time at depth for two manatees in a central Belize lagoon. Visual inspection of figure 8 from Nowacek et al. (2002) resulted in the depth distribution in table 102. The manatees were located in water that ranged 1.5–10.5 m deep. The average time spent in portions of the water column was 80% in less than 3 m of water and 57% in less than 1.5 m of water. This is consistent with the behavior of their closest relative, the dugong, which spent 72% and 47% of their time in the top 3 m and 1.5 m, respectively. Dugongs are obligate benthic foragers, whereas manatees forage throughout the water column, and, therefore, might be expected to spend more time at depth (Wells et al., 1999).

Table 102. Percentage of Time at Depth for the West Indian Manatee

Depth Bin (m)	Percentage of Time at Depth		
	Animal		Average
	M-9	M-10	
0-0.5	5.6	5.7	5.65
0.5-1	12.31	30.14	21.23
1-1.5	8	52.34	30.17
1.5-2	3.4	11.81	7.61
2-2.5	8	0.01	4.01
2.5-3	23.34	0	11.67
3-3.5	39.34	0	19.67
3.5-4	0.01	0	0.01

2.5.4 Sea Turtles

2.5.4.1 Family Dermochelyidae

2.5.4.1.1 Dermochelys coriacea, Leatherback Turtle. The leatherback turtle is distributed circumglobally in tropical, subtropical, and warm-temperate waters throughout the year and into cooler temperate waters during warmer months (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1993; James et al., 2005a) as far north as Nova Scotia, Newfoundland, Labrador, Iceland, the British Isles, and Norway (Bleakney, 1965; Brongersma, 1972; Threlfall, 1978; Goff and Lien, 1988). In the Pacific, they extend from waters of British Columbia (McAlpine et al., 2004) and the Gulf of Alaska (Hodge and Wing, 2000) to the waters of Chile and New Zealand. The leatherback is the most oceanic and wide-ranging of sea turtles, undertaking extensive migrations for hundreds to thousands of kilometers (Morreale et al., 1996; Hughes et al., 1998). 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; Threlfall, 1978; Goff and Lien, 1988).

Atlantic:

Leatherback nesting occurs on isolated mainland beaches in tropical (mainly Atlantic and Pacific, few in Indian Ocean) and temperate oceans (southwest Indian Ocean) (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1992) and to a lesser degree on some islands, such as the Greater and Lesser Antilles. In the U.S., the densest nesting is in Florida along the Atlantic coast from Jensen Beach south to Palm Beach (Stewart and Johnson, 2006). Sporadic nesting occurs in Georgia, South Carolina, and as far north as North Carolina (Rabon Jr. et al., 2003).

According to aerial survey data, there is a northward movement of individuals along the southeast coast of the United States in the late winter/early spring. In February and March, most leatherbacks along the U.S. Atlantic coast are found in the waters off northeast Florida. By April and May, leatherbacks begin to occur in larger numbers off the coasts of Georgia and the Carolinas (50 CFR § 217 222 & 227, 1995; 50 CFR § 222 & 223, 2000). In late spring/early summer, leatherbacks appear off the mid-Atlantic and New England coasts, while by late summer/early fall, many will have traveled as far north as the waters off eastern Canada remaining in the northeast from approximately May through October (Cetacean and Turtle Assessment Program (CETAP) ,1982; Shoop and Kenney, 1992; Wyneken et al., 2005). Leatherback foraging areas in the western Atlantic are located on the continental shelf (30° to 50° N) as well as offshore (42° N, 65° W) (Eckert, 2006). The location of these foraging areas changes seasonally. From March through November, foraging areas occur on the North American continental shelf yet shift to off-shelf waters from December through February (Eckert, 2006).

Pacific:

Some of the largest nesting populations of leatherback turtles used to occur in the Pacific Ocean, but no nesting occurs on beaches under U.S. jurisdiction. In the Pacific, leatherback turtles are from two distinct stocks: the Western Pacific and the Eastern Pacific. In the western Pacific, the major nesting beaches occur in Indonesia, Papua New Guinea, the Solomon Islands, and Vanuatu. These nesting aggregations consist of approximately 2,700–4,500 breeding females. In the eastern Pacific, the major nesting beaches are found in Costa Rica and Mexico, although traditionally, nesting occurred along the Pacific coast from Baja California to Panama. The leatherback is typically associated with continental shelf habitats and pelagic environments. It is uncommon in the insular Pacific, but individuals are sometimes encountered in deep water near prominent archipelagoes. To a large extent, the oceanic distribution of leatherbacks may reflect the distribution and abundance of macro-planktonic prey.

In the western Pacific, satellite telemetry work demonstrated migrations of leatherbacks nesting in Papua, Indonesia, to the waters of the Philippines and Malaysia, into the Sea of Japan, and across the equatorial Pacific to temperate waters off North America where they forage in the continental shelf waters of the U.S. west coast (Benson et al., 2007). Leatherbacks occur north of central California during the summer and fall, when sea surface temperatures are highest (Dohl, 1983; Brueggeman, 1991). There is some evidence that they follow the 61ºF (16ºC) isotherm into Monterey Bay, and the length of their stay apparently depends on prey availability (Starbird et al,. 1993). Some aerial surveys of California, Oregon, and Washington waters suggest that most leatherbacks occur in continental slope waters and fewer occur over the continental shelf. There were 96 sightings of leatherbacks within 50 km of Monterey Bay from 1986 to 1991, mostly by recreational boaters (Starbird et al., 1993). Fishermen "regularly" catch leatherbacks in drift/gill nets off Monterey Bay (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998c). Leatherbacks encountered in Hawaii, including those caught incidental to fishing operations, may represent individuals in transit from one part of the Pacific to another (Balazs 1976). Leatherbacks are "regularly sighted" in offshore waters at the southeastern end of the Hawaiian archipelago. In August 1979, at least ten individuals, including juveniles, were sighted in pelagic waters northwest of Hawaii (40–42º N, 175–179º W) (Balazs, 1982).

In the eastern Pacific, satellite telemetry data indicated these animals migrate south into the southeastern Pacific and forage off the west coast of South America (i.e., Chile). Leatherbacks nesting in Papua, Indonesia and Papua New Guinea forage in both the western and eastern Pacific, whereas the eastern Pacific population forages primarily in the southeastern Pacific (Donoso et al., 2000).

Dive Profile Information

The leatherback turtle is a Tier 2 species. Depth distribution data recorded in table 103 are from Houghton et al. (2008a). The data recorded in this study are a composite of information from previously published works, including Hays et al. (2004), Hays et al. (2006), McMahon and Hays (2006), and Doyle et al. (2008). The data represents the average of 13 satellite tagged adult leatherbacks (12 females, 1 male). Eleven females were tagged at nesting beaches in the Caribbean (Levera Beach, Grenada, West Indies). Two individuals (1 male, 1 female) were tagged at foraging grounds off the Dingle Peninsula in Kerry, Ireland. The turtles were tracked for an average of 270.6 days (range: 2–406 days). The data include dive profile information for several behavioral states: post-nesting, migration, and foraging. Figure 1 illustrates the geographic extent of the study.

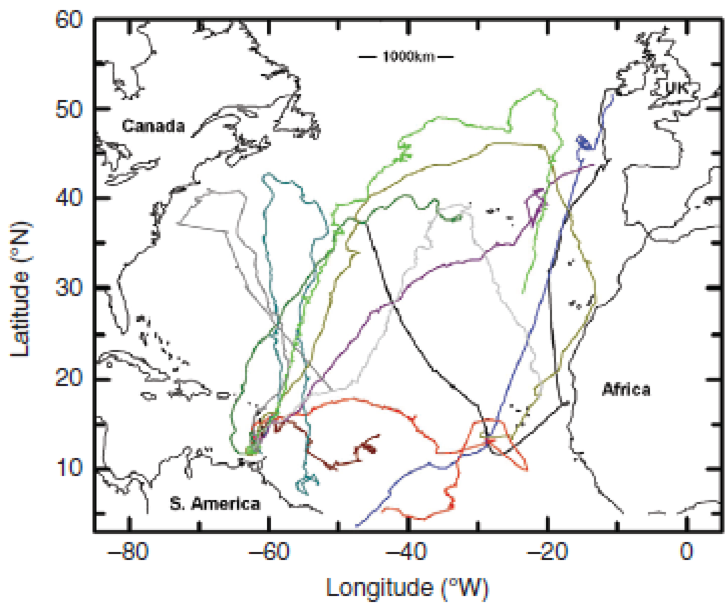

Figure 1. Movements of Leatherbacks Tracked Between 2002–2006 (Houghton et al., 2008b)

Table 103. Percentage of Time at Depth for the Leatherback Turtle

Depth Bin (m)	Percentage of Time at Depth
0-10	18.928
11-100	65.264
101-200	14.626
201-300	0.818
301-400	0.119
401-500	0.103
501-600	0.069
601-700	0.023
701-800	0.015
801-900	0.015
901-1000	0.008
1001-1100	0.004
1101-1200	0.000
1201-1280	0.008

Table 104. Movement Behavior Variables from Houghton et al. (2008b) (and Supporting Studies)

Location	Variable	Value	Reference
Caribbean	Average Depth	51.7 +/- 39.9 m	Hays et al. (2006)
	Average Dive Time	10.95 +/- 6.13 min	Hays et al. (2006)
Atlantic	Average Depth	76.7 +/- 65.3 m	Hays et al. (2006)
	Average Dive Time	25.87 +/- 8.27 min	Hays et al. (2006)
Overall	Average Depth	53.9 +/- 50.8 ms	Houghton et al. (2008b)
	Max Depth	1,280 m	Doyle et al. (2008)
	Max Dive Time	68.5 min	Doyle et al. (2008)

General Dive Behavior Information:

Eighty percent of the leatherback's time at sea is spent diving (Fossette et al. 2007). 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 (e.g., (Hays et al., 2004; Sale et al., 2006). Diving activity (including surface time) is influenced by a suite of environmental factors (i.e., water temperature, availability, and vertical distribution of food resources, bathymetry) that result in spatial and temporal variations in dive behavior (James et al., 2006a; James et al., 2006b; Sale et al., 2006). 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).

Tag data has revealed that during inter-nesting periods, dives are likely constrained by bathymetry adjacent to nesting sites (Hays et al. 2006; Myers and Hays 2006). For example, patterns of relatively deep diving are recorded off St. Croix in the Caribbean (Eckert et al., 1986) and Grenada (Myers and Hays, 2006) in areas where deep waters are close to shore. A maximum depth of 475 m was recorded by Eckert et al.(1986), while even deeper dives have been inferred where dives exceeded the maximum range of the time depth recorder (Eckert et al., 1989a). Where shallow water is close to the nesting beach, shallow diving occurs in the China Sea (Eckert et al., 1996), Costa Rica (Southwood et al., 1999), and French Guiana (Fossette et al., 2007).

While transiting, leatherbacks make longer and deeper dives (Jonsen et al., 2007). 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). Leatherbacks spend the majority of their time in the upper 65 m of the water column, regardless of their behavior (Jonsen et al., 2007). The aerobic dive limit for the leatherback turtle has been estimated between 33 and 67 min (Southwood et al., 1999; Hays et al., 2004; Wallace et al., 2005), although Sale et al. (2006) reported maximum durations of up to 82 min off South Africa. In the Atlantic, Hays et al. (2004) determined that leatherbacks spent 71–94 % of their diving time at depths from 70 to 110 m. Eckert et al. (1989b) observed a mean dive duration for Caribbean leatherbacks of 9.9 min with a 4.9 min surface interval time, while Fossette et al. (2008) reported that individual dives averaged 6.6 min with post-nesting dives typically shorter than 8 min.

2.5.4.2 Family Cheloniidae

2.5.4.2.1 Chelonia mydas, Green Turtle. The green turtle has a circumglobal 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. Nesting occurs in more than 80 countries worldwide (Hirth, 1997), and they are believed to inhabit coastal waters of at least 140 countries (Groombridge and Luxmoore, 1989).

After they emerge from the nest, hatchlings swim to offshore areas where they float passively in major current systems (gyres). Once reaching the juvenile stage (estimated at 5–6 years and carapace length of 20–25 cm), they 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). This is where they will spend the majority of their lives (Bjorndal and Bolten, 1988; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (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 (Pelletier et al. 2003; National marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007a). After 5 or 6 years in this habitat, larger juveniles and subadults may migrate to new habitats. 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).

<u>Atlantic:</u>

Green turtles found in U.S. waters come from nesting beaches widely scattered throughout the Atlantic (Witherington et al., 2006). In U.S. Atlantic and Gulf of Mexico waters, green turtles are found around the U.S. Virgin Islands, Puerto Rico, and along the continental United States from Texas to Massachusetts (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1991). Juvenile green turtles utilize estuarine waters along the U.S. Atlantic coast as summer developmental habitat, as far north as Long Island Sound, Chesapeake Bay, and North Carolina sounds (Epperly et al., 1995a; Epperly et al., 1995b; Musick and Limpus, 1997). Nearshore water temperatures play a major role in determining green turtle distribution along the Atlantic and gulf coasts of the United States (Musick and Limpus, 1997; Witherington et al., 2006). Adults are predominantly tropical and are only occasionally found north of southern Florida. Most sightings of individuals north of Florida occur between late spring and early fall, and are of juveniles (Lazell Jr., 1980; Cetacean and Turtle Assessment Program (CETAP), 1982; Burke et al., 1992; Epperly et al., 1995a). Optimal feeding habitats for green turtles in the continental U.S. include waters in Florida and southern Texas such as the Indian River Lagoon, Florida Keys, Florida Bay, Homosassa Springs, Crystal River, Cedar Keys, and Laguna Madre Complex (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1991; Hirth, 1997). The inshore waters of North Carolina are also an important feeding habitat for juveniles of this species (Epperly et al., 1995a).

Green turtles nest on both island and continental beaches between 30º N and 30º S (Witherington et al., 2006). Although Florida is near the northern extent of the green turtle's Atlantic nesting range, it hosts a significant proportion of green turtle nesting (Witherington et al., 2006). Green turtle nesting in Florida has occurred in every coastal county except those bordering the Big Bend area (Meylan et al., 1995; Witherington et al., 2006). Approximately 99 % of the green turtle nesting in Florida occurs on the Atlantic coast, with Brevard through Broward counties hosting the greatest nesting activity (Meylan et al., 1995; Witherington et al., 2006). There are scattered nesting records in Georgia, and the Carolinas (Peterson et al., 1985; Schwartz, 1989; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1991).

Pacific:

The west coasts of Central Mexico, and the United States constitute a shared habitat for East Pacific green turtles (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998a). Along the Pacific coast of the U.S., East Pacific green turtles have been reported as far north as British Columbia (48.15° N) (Eckert, 1993; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998c). Stinson (1984b) reviewed sea turtle sighting records from northern Baja California to Alaska and concluded that the East Pacific green turtle was the most commonly observed hard-shelled sea turtle on the U.S. Pacific coast.

Green turtles typically migrate along coastal routes from rookeries to feeding grounds, although some populations conduct transoceanic migrations. South of the United States, green turtles are widely distributed in the coastal waters of Mexico and Central America (Cliffton et al., 1982; Cornelius and Robinson, 1986b). The main aggregations of East Pacific green turtles occur in the breeding grounds of Michoacán, Mexico from August through January and year-round in the feeding areas, such as those located on the west coast of Baja California, along the coast of Oaxaca, and in the Gulf of California (Sea of Cortez) (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998c). Bahía de Los Angeles in the Gulf of California has been identified as an important foraging area for green turtles (Seminoff et al., 2003a).

The largest nesting colony in the central Pacific Ocean occurs at French Frigate Shoals in the Northwestern Hawaiian Islands, where about 200 to 700 females nest each year. Green turtles occur in the coastal waters surrounding the Main Hawaiian Islands throughout the year and also migrate seasonally to the Northwestern Hawaiian Islands to reproduce. Adult green turtles that breed in the Northwestern Hawaiian Islands make regular reproductive migrations from their foraging grounds either around the Main Hawaiian Islands or around the westernmost atolls in the Northwestern Hawaiian Islands. This has been evidenced by mark recapture and satellite-tracking studies on both adult male and female green turtles (Balazs, 1976; Balazs et al., 1994; Balazs and Ellis, 1998). Juvenile green turtles can also make long-range movements throughout the Hawaiian archipelago.

Dive Profile Information:

The green turtle is a Tier 2 species. Depth distribution data recorded in table 105 is adapted from Godley et al. (2002). The data recorded in this study represent the average of data from six, female, satellite-tracked green turtles. The turtles were tagged while nesting on beaches in northern Cyprus. The turtles were tracked for a period ranging from 8 to 44 days. The data include dive profile information for several behavioral states: post-nesting, migration, and foraging. Figure 2 illustrates the geographic extent of the study. The distance covered by the turtles ranged from 320–2,200 km.

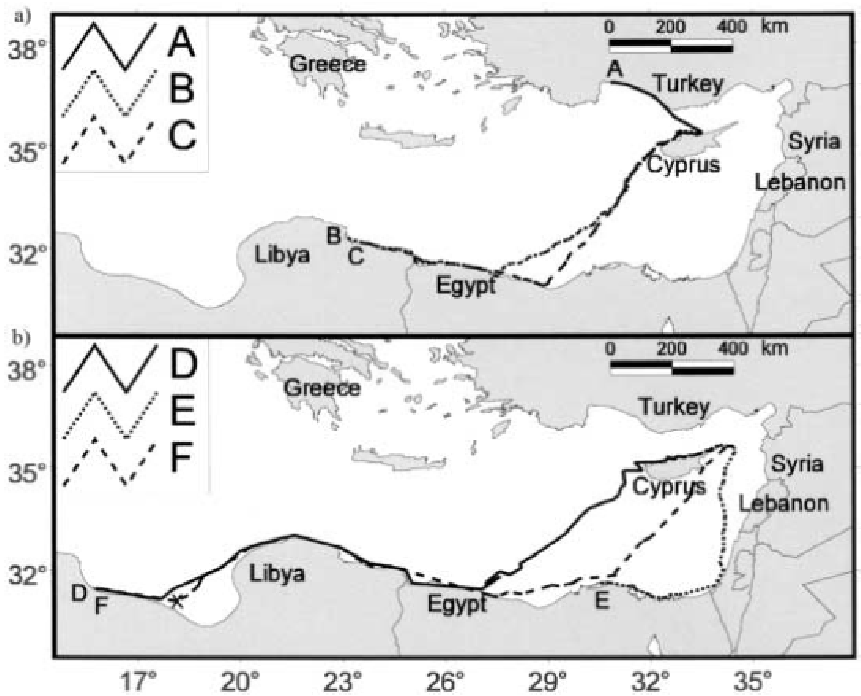

Figure 2. Movements of Green Turtles Tracked Between 1998–1999 (Godley et al., 2002)

Table 105. Percentage of Time at Depth for the Green Turtle (Godley et al., 2002)

Depth Bin (m) [a]	Percentage of Time at Depth						
	During Traveling			At Foraging Grounds			Average[b]
	Cyprus Coastal Waters	Open-ocean Crossing	Along Coasts of Turkey/N. Africa	Prior to wintering	During Over-wintering	Post-wintering	
0-5	55.67	77.17	46.2	74.5	31.5	70.33	59.23
6-10	26.17	3.67	15.03	21.33	27	8.67	16.98
11-15	11.67	5.83	14.77	4.17	25.33	8.33	11.68
16-20	6.5	4.17	9.67	0	14	6.33	6.78
21-25	0	4.5	6.83	0	1.67	2.67	2.61
26-30	0	2.33	3.67	0	0.5	1.83	1.39
31-35	0	1.67	0.9	0	0	1.83	0.73
36-40	0	0.67	0.9	0	0	0	0.26
41-45	0	0	0.33	0	0	0	0.06
45-138	0	0	1.7	0	0	0	0.28

[a] 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, the Northwester Hawaiian Islands (NWHI) 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.
[b] The percentage of time that green turtles spent in each behavioral state (i.e., traveling versus foraging) was not reported in the publication. The small sample size (6 turtles) and variable duration of tag attachment per turtle (28–293 days) did not allow for further analysis to determine an appropriate weighting function that could be applied to each behavioral state to more accurately depict a dive depth distribution for the green turtle. As a result, the time spent in each behavioral state was assumed to be equal and was averaged for a composite dive depth distribution.

Table 106. Movement Behavior Variables from (Godley et al., 2002)

Location	Variable	Value	Reference
Mediterranean Sea	Distance Traveled (km)	320 to 2200 km	Godley et al. (2002)
	Travel Rate (km/hr)	Open ocean crossing: 2.8 km/hr Cyprus coastal waters: 1.6 km/hr Turkish/N. Africa coasts: 1.7 km/hr	
	Max Dive Depth (m)	> 45 m (Tag unable to define exact depth)	
	Max Dive Duration (min)	> 90 min (Tag unable to define exact time)	
	Percent Time at the Surface	Open-ocean crossing: 49 +/- 21.3 Cyprus coastal waters: 23.3 +/- 25.3 Turkish/N. Africa coasts: 17.3 +/- 14.3	

General Dive Behavior Information:

Three Pacific studies (Brill et al., 1995; Hatase et al., 2006a; Rice and Balazs, 2008) and one Atlantic study (Hays et al., 2004) assessed green turtle diving physiology. Detailed dive profile information was not able to be obtained from the authors of these studies; however, some behavioral variables were contained within the text of these publications and are presented below. In the open ocean, Hatase (2006b) observed that green turtles dive to a maximum of 80 m, while green turtles migrating between the northwestern and main Hawaiian Islands reached a maximum depth greater than 135 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 (Hochscheid et al., 1999; Hays et al., 2000; Godley et al., 2002; Hatase et al., 2006a) and often not exceeding 17.5 m (Hays et al., 2004; Rice and Balazs, 2008). A maximum dive duration of 66 min was observed on a juvenile Hawaiian green turtle (Brill et al., 1995). Green turtles are known to forage and also rest at depths of 20–50 m (Balazs, 1980; Brill et al., 1995).

2.5.4.2.2 Eretmochelys imbricata, Hawksbill 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. Only five regional populations worldwide remain with more than 1,000 females nesting annually–two in Australia, and one each in Indonesia, Seychelles, and Atlantic Mexico (Meylan and Donnelly, 1999).

Hatchlings are believed to occupy pelagic waters, associating themselves with surface algal mats and other floating debris in the Atlantic (Witzell, 1983; Parker, 1995; Witherington and Hirama, 2006). Juveniles leave the pelagic habitat after 3–4 years and recruit to coastal foraging areas (typically coral reefs, but occasionally sea grass beds, algal beds, mangrove bays, and creeks (Mortimer and Donnelly, 2008). Tag-return, genetic, and telemetry studies have all indicated that Caribbean hawksbill turtles use multiple developmental habitats as they progress from age class to age class. However, some hawksbills choose to be sedentary within a specific developmental habitat for a long period of time during a given life stage, such as the later juvenile stage (Meylan and Donnelly, 1999). 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 (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998b). In neritic habitats, resting areas for late juvenile and adult hawksbills are typically located in deeper waters, such as sandy bottoms at the base of a reef flat (Houghton et al., 2003). Late juveniles generally reside on shallow reefs less than 18 m deep; however, as they mature into adults, hawksbills move to deeper habitats and may forage to depths greater than 90 m. Benthic-stage hawksbills are seldom found in waters beyond the continental or insular shelf unless they are in transit between distant foraging and nesting grounds (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1993). Ledges and caves of coral reefs provide shelter for resting hawksbills both during the day and at night, and they are known to inhabit the same resting spot night after night. Hawksbills are also found around rocky outcrops and high-energy shoals—optimum sites for sponge growth—as well as mangrove-fringed bays and estuaries where coral reefs are absent (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007b).

Hawksbills were originally thought to be a non-migratory species as a result of both the close proximity of suitable nesting beaches to coral reef feeding habitats, and the high rates of local recapture. However, tagging studies have shown otherwise. For example, a subadult tagged in Brazil was captured in Gabon with a straight-line migration distance of 4,669 km (Bellini et al., 2000). In the Indo-Pacific, a post-nesting female traveled 1,600 km between the Solomon Islands and Papua New Guinea (Meylan et al., 1995). A female tagged at Buck Island Reef National Monument in the U.S. Virgin Islands traveled 1,866 km to the Miskito Cays in Nicaragua (Spotila, 2004). This research indicates that adult hawksbill turtles are capable of migrating distances comparable to green and loggerhead turtles.

Atlantic:

Hawksbills are widely distributed throughout the Caribbean Sea and western Atlantic Ocean, regularly occurring in the nearshore waters of southern Florida and the Gulf of Mexico (especially Texas), in the Greater and Lesser Antilles, and along the Central American mainland south to Brazil (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007b). In the continental U.S., the species is recorded from all the Gulf States and along the east coast as far north as Massachusetts, but sightings north of Florida are rare, and Texas is the only other U.S. state where hawksbills are sighted with any regularity (Lee and Palmer, 1981; Keinath et al., 1991; Plotkin et al., 1994; Parker, 1995). Small numbers of hawksbill occurrences are documented from winter to summer from southeastern Florida (Palm Beach, Broward, and Dade Counties) through the Florida Keys to coastal waters just northwest of Tampa Bay, where the northernmost stranding records occur. However, the greatest number of hawksbill turtles is found in the fall off southern Florida. Small populations of foraging juveniles and adults recruit to coral reef and hard bottom habitats off southern Florida throughout the year. Hawksbills are observed rarely in waters off the Florida Panhandle, Alabama, Mississippi, Louisiana, and Texas (Rabalais and Rabalais, 1980; Witzell, 1983; Rester and Condrey, 1996). Hawksbill sightings in these areas likely involve early juveniles that are born on nesting beaches in Mexico and have drifted north with the dominant currents (Landry and Costa, 1999).

In the most recent stock assessment for the hawksbill turtle, nesting trends at 33 sites within the Atlantic Ocean were evaluated. Thirty occur in the Caribbean, one in Brazil, and two minor aggregations in West Africa. In Mexico, between 534 and 891 hawksbill nests are laid on the Yucatan Peninsula (Campeche, Yucatán, and Quintana Roo) each year (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c) with an estimated 1,900–4,300 adult females comprising the entire Mexican Atlantic nesting population (Garduño-Andrade et al., 1999). The most significant nesting within the U.S. occurs on Mona Island in Puerto Rico, where between 332 and 399 hawksbill nests are laid annually, and on Buck Island Reef National Monument off St. Croix in the U.S. Virgin Islands, where 100 to 150 nests are laid annually (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c). Nesting in Florida is believed to be extremely rare, although some nests may be missed due to thousands of loggerheads nesting along the same stretches of beach (Lund, 1985).

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 environment in the Atlantic Ocean.

Pacific:

A lack of regular quantitative surveys for hawksbill turtles in the Pacific Ocean and the poorly understood nature of this species' nesting have made it extremely difficult for scientists to assess the distribution and population status of hawksbills in the Pacific (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998b; Seminoff et al., 2003b). Along the far western and southwestern Pacific, hawksbills nest on islands and mainland Asia from

China and Japan, through the Philippines, Malaysia, and Indonesia to Papua New Guinea and the Solomon Islands (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c). Hawksbills nest sporadically in the southern part of the Baja peninsula, while sightings of juveniles and subadults foraging along the coast occur more regularly. Hawksbills rarely occur along the Pacific Central American coast. No nesting occurs on the west coast of mainland United States. Limited nesting has been documented on the Pacific coast of Costa Rica (Gaos et al., 2006). Nesting is widely distributed within the Central Pacific, though scattered and in very low numbers. The largest populations in the Central Pacific occur in Micronesia and Vanuatu, with approximately 300 females nesting each year. Hawksbills in the U.S. Pacific nest only on main island beaches in Hawaii (5–10 nesting females annually), primarily along the east coast of Hawaii island. Hawksbill nesting has also been documented in American Samoa and Guam (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c).

Foraging hawksbills have been reported from virtually all of the island groups of Oceania, and from the Galapagos Islands in the eastern Pacific to the Republic of Palau in the western Pacific (Witzell, 1983; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c). In U.S. waters, hawksbills predominantly occur in the coastal waters of the eight main and inhabited islands of the archipelago. Hawksbill are only rarely found in the NWHI, and then only as stranded or injured (Parker et al., 2009). Hawksbill turtles are the second most common species in the offshore waters of the Hawaiian Islands, as reflected by the stranding records, yet they are far less abundant than green turtles. Throughout the year, the area of primary occurrence for hawksbill turtles can be found in Hawaiian waters shoreward of the 100 m isobath. Hawksbills are known to forage around the main Hawaiian Islands. Coral reefs and hardbottom areas are their preferred habitats, which are seldom found in waters deeper than the shelf break. Beyond this isobath, hawksbill occurrence is apparently rare year-round. The occurrence of the hawksbill turtle is rare throughout the year along the U.S. west coast, and its potential to occur in this region extremely low. If hawksbills were to occur in this region, it would most likely be during an El Niño event, as they are a highly tropical species.

While hawksbills are known to occasionally migrate large distances, possibly in the open ocean, this is the most coastal of all marine turtles. In addition, as with all turtles, the post-hatchling and early juvenile phase is assumed to occur in the pelagic environment. However, there is very little available information on hawksbills in the pelagic environment in the Pacific Ocean.

Dive Profile Information:

The hawksbill turtle is a Tier 2 species. Depth distribution data recorded in table 107 and table 108 are from van Dam and Diez (1996) and Blumenthal et al. (2009a). Table 109 represents a typical dive profile for hawksbill turtles and is an average of the data collected in van Dam and Diez (1996) and Blumenthal et al. (2009a).

The data recorded in van Dam and Diez (1996) represent an average of data from four immature hawksbills captured off the northwestern cliffs of Mona Island, Puerto Rico. The turtles were tracked for a 10–11 days each and covered an average distance of 0.99 km (range: 0.11–1.98 km). Figure 3 illustrates the geographic extent of the study. The data collected represents foraging and resting dive behavior for resident juvenile hawksbill turtles. The data recorded in Blumenthal et al. (2009a) represent an average of data from eighteen immature hawksbills captured in Blood Bay, Cayman Islands in 2005. Time depth data were 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). The distance traveled from their initial capture site averaged 530 ± 466 m with a range of 63–2,080 m. Figure 4 illustrates the geographic extent of the study. The data collected represents foraging and resting dive behavior for juvenile hawksbill turtles.

Both datasets which were used to derive the depth profile distribution for hawksbill turtles were from immature (juvenile) turtles. Ideally, data from adult specimens is 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). Although generally as marine turtles mature they gain a more refined control of their buoyancy. To, date, however, there have been no projects where a large number of time depth recorders (TDRs) 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., 2009b). As a result, the data obtained from studies with juvenile turtle represents the best available data and should be interpreted as generally representative across the entire hawksbill population.

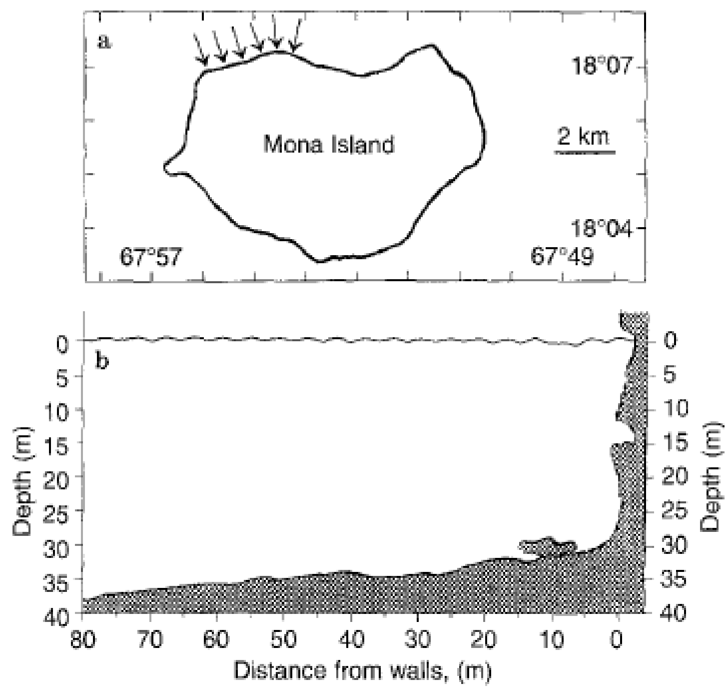

Figure 3. Habitat Utilized by Hawksbill Turtles Tracked off Mona Island in 1994 (van Dam and Diez, 1996)

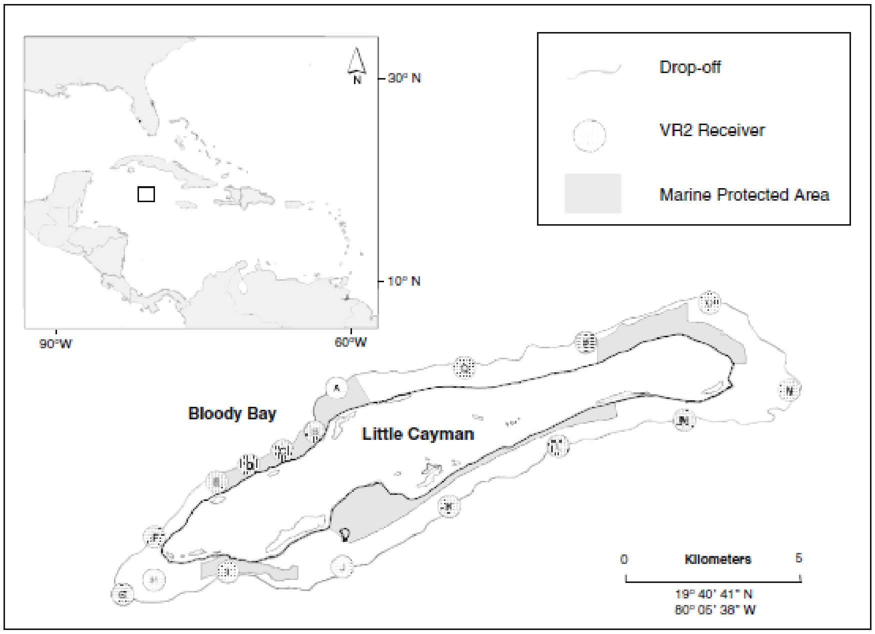

Figure 4. Habitat Utilized by Hawksbill Turtles Tracked from Blood Bay, Cayman Islands in 2005 (Blumenthal et al., 2009a)

Table 107. Percentage of Time at Depth for the Hawksbill Turtle off a Cliff Wall in Puerto Rico (van Dam and Diez, 1996)

Depth Bin (m)	Percentage of Time at Depth
0-2	17.25
3-10	75
11-20	5.1
21-30	1.6
31-40	0.8
41-50	0.2
51–72.1	0.05

Table 108. Percentage of Time at Depth for the Hawksbill Turtle on Coral Reefs in Cayman Islands (Blumenthal et al. 2009a)

Depth Bin (m)	Percentage of Time at Depth		
	Shallow Diver	Deep Diver	Average
0-2	4	6.75	5.375
3-10	96	19	57.5
11-20	0	35.75	17.875
21-30	0	15.5	7.75
31-40	0	12.75	6.375
41-50	0	7.75	3.875
51-91	0	2.5	1.25

Table 109. Percentage of Time at Depth for the Hawksbill Turtle (Averaged from (van Dam and Diez, 1996; Blumenthal et al., 2009a)

Depth Bin (m)	Percentage of Time at Depth
0-2	11.3125
3-10	66.25
11-20	11.4875
21-30	4.675
31-40	3.5875
41-50	2.0375
51-91	0.65

Table 110. Movement Behavior Variables from (van Dam and Diez, 1996; Blumenthal et al., 2009a)

Location	Variable	Value	Reference
Mona Island, Puerto Rico	Distance Traveled (km)	Average: 0.99 km Range 0.11 to 1.98 km	van Dam and Diez (1996)
	Dives per day	73.6 +/- 0.975 dives per day	
	Average Dive Depth (m)	4.8 +/- 0.175	
	Max Dive Depth (m)	72.1 meters	
	Average Dive Duration (min)	19.175 +/- 0.475 min	
	Max Dive Duration (min)	81.1 minutes	
	Average Surface Interval	33.7 +/- 0.65 seconds	
	Percent Time at the Surface	Daytime: 3.6 Night: 1.8	
Bloody Bay, Cayman Islands	Distance Traveled (km)	Average: 0.530 +/- 0.466 km Range: 0.063 – 2.080 km	Blumenthal et al. (2009a)
	Average Dive Depth (m)	Day: 8 +/- 5 m Night: 5 +/- 5 m	
	Max Dive Depth (m)	91 m	
	Average Dive Duration (min)	Day: 16 +/- 7 min Night: 25 +/- 14 min	
	Max Dive Duration (min)	53 min	

General Dive Behavior Information:

Foraging dive durations are often a function of turtle size with larger turtles diving deeper and longer. Shorter and more active foraging dives predominantly occur during the day, while longer resting dives occur at night (van Dam and Diez, 1996; Storch et al., 2005; Blumenthal et al., 2009a). 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. van Dam and Diez (1996) reported foraging dives at a study site in the northern Caribbean ranged from 19 to 26 min at depths of 8–10 m, with resting, night dives from 35 to 47 min. 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; (van Dam and Diez, 1996; Lutcavage and Lutz, 1997; Blumenthal et al., 2009a) cited a maximum dive duration of 73.5

min for a female hawksbill in the U.S. Virgin Islands. 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).

2.5.4.2.3 Lepidochelys kempii, Kemp's ridley Turtle. The Kemp's ridley has one of the smallest ranges of all marine turtle species, occurring primarily in the coastal waters of the Gulf of Mexico from the Yucatán peninsula to South Florida. Habitats frequently utilized by Kemp's ridley turtles in U.S. waters include warm-temperate to subtropical sounds, bays, estuaries, tidal passes, shipping channels, and beachfront waters where their preferred food, the blue crab, is known to exist (Lutcavage and Musick, 1985; Landry and Costa, 1999; Seney and Musick, 2005). The distribution of the Kemp's ridley population is most concentrated in the Gulf of Mexico with year round occurrence throughout the Gulf and southern Atlantic coasts of Florida, and seasonal occurrence along the Atlantic coast as far north as Nova Scotia, Canada (Lazell Jr., 1980; Morreale et al., 1992).

Atlantic:

During the spring and summer months, juvenile Kemp's ridleys occur in the shallow coastal waters of the Northern Gulf of Mexico, from South Texas to northern. In the fall, most Kemp's ridleys migrate to deeper or more southern warmer waters and remain there through the winter (Ogren, 1989; Schmid, 1998). Key foraging sites in the Northern Gulf of Mexico include Sabine Pass, Texas; Caillou Bay and Calcasieu Pass, Louisiana (Ogren, 1989; Landry Jr. et al., 1995; Schmid, 1998; Landry Jr. et al., 2005); Big Gulley, Alabama; and Apalachicola, Apalachee, Deadman, and Waccasassa Bays, Florida (Schmid and Barichivich 2005, 2006), Witzell, 2007). Important year-round developmental habitats in the Northern Gulf of Mexico include the western coast of Florida (particularly the Cedar Keys area), the eastern coast of Alabama, and the mouth of the Mississippi River (Lazell Jr., 1980; Lutcavage and Musick, 1985; Marquez, 1990; National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1992; Márquez-Millán, 1994; Weber, 1995; Landry Jr. et al., 1996; Schmid et al., 2002). The coastal waters off western Louisiana and eastern Texas also provide adequate habitats for benthic feeding.

Recent tagging studies indicate that neritic juveniles occupy the Florida waters when water temperatures are above 20ºC (Schmid, 1998; Schmid and Barichivich, 2005; Schmid and Barichivich, 2006). Key foraging sites include Charlotte Harbor and Gullivan Bay, Florida (Schmid and Barichivich, 2005). In addition, the offshore waters south of Cape Canaveral have been identified as an important overwintering area for turtles foraging in the coastal waters of the U.S. Atlantic (Henwood and Ogren, 1987; Schmid, 1995). Satellite telemetry data suggest that turtles migrate south in October and November from Georgia and northern Florida to the waters south of Cape Canaveral, and return to their summer foraging grounds in March and April. As such, higher densities of Kemp's ridleys in the Florida waters are likely in the winter months.

North of Florida, Kemp's ridleys occur in moderate numbers along the U.S. northeast coast as far as Nova Scotia, Canada (Lazell Jr., 1980; Morreale et al., 1992). Recent analysis of sightings and strandings from the eastern Atlantic may indicate that as the population size increases, the range of Kemp's ridleys may be expanding into the eastern Atlantic and Mediterranean (Witt et al., 2007). Juvenile Kemp's ridleys have been studied in Pamlico Sound, North Carolina, Chesapeake Bay, Virginia, and Long Island Sound, with activity occurring in the warmer summer months.

The primary nesting beach for Kemp's ridley turtles is near Rancho Nuevo in Tamaulipas, Mexico, with a smaller nesting population in Veracruz, Mexico in the Southern Gulf of Mexico. A number of beaches along the Texas, Alabama, and Florida coasts have reported low levels (less than 10 nests per year) of Kemp's ridleys, with Padre Island National Seashore supporting the largest U.S. nesting aggregation (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2010).

Dive Profile Information:

The Kemp's ridley turtle is a Tier 2 species that will be represented by a surrogate species, the green turtle (section 2.5.4.2.1). Very few studies have been conducted regarding the movement, migration, and diving capabilities of Kemp's ridley turtles. While past studies have described Kemp's ridley diving behavior, results were only generalized accounts of diving behavior due to the limited capabilities of the VHF radio, sonic, and satellite telemetry equipment used in these studies. Only a couple of studies exist for which satellite tags were deployed that had the ability to record detailed time-depth information (i.e., Renaud and Williams (1997)–Lacava and Matagorda Bays, TX; Sasso and Witzell (2006)–Gullivan Bay, FL). Unfortunately, the locations in which they were deployed were all extremely shallow habitats (0.3–6 m), and dive behavior was probably depth-limited calling into question the reliability of the data. Immature Kemp's ridleys tagged in Lacava and Matagorda Bays, TX by Renaud and Williams (1997), spent over 90% of their time in water depths less than 1.5 m. The average dive depth for an immature Kemp's ridley tagged in Gullivan Bay was 2.29 +/- 0.56 m with a maximum dive depth recorded of 5.27 m (Sasso and Witzell, 2006).

General migration and movement data indicate that Kemp's ridley turtles generally utilize waters less than 50 m in depth as adults, and even shallower waters as juveniles. Byles and Plotkin (1994) noted that 18 adult females stayed in waters less than 50 m in depth during post-nesting movements in the Gulf of Mexico after nesting in Tamulipas, Mexico. This was supported by Renaud (1995a) which reported that juvenile Kemp's ridleys occupy coastal waters of < 20 m depth and adults remain in offshore areas of depths < 50 m. The percentage of locations within the 10-fathom (18-m) depth contour recorded for the four turtles tagged in Renaud (1995a) were 85%, 96%, 87%, and 29%, respectively. Juvenile Kemp's ridley tagged by Gitschlag (1996) had their final locations recorded in waters ranging in depth from 18–24 m.

More recently, data compiled in Shaver et al. (2005) for 11 adult male in the Gulf of Mexico (Tamulipas, Mexico) showed that the majority of locations were recorded in waters of 20 fathoms (37 m) or less. Decreasing numbers of locations were found between the 20 to 100 fathom curves (37–183 m). Only 4 locations were recorded beyond the 100 fathom curve (183 m), however, these locations were of poor location classes and were questionable as to their authenticity. Shaver and Rubio (2007) noted similar results for 28 adult females after nesting in North Padre and Mustang Island, TX. Most of the locations in the nearshore Gulf of Mexico waters were within the 20 fathom curve (< 37 m water depth). Lastly, Seney and Landry (2008) found that 6 adult females spent 80% of their time in locations with waters < 10 m after nesting in Galveston, TX. Migration along the TX and LA coastlines were predominantly in waters < 20 m. Foraging in Louisiana occurs in water depths ranging from 10–30 m (Seney and Landry, 2008).

Based on this data, not enough information exists from which to derive a dive profile for the Kemp's ridley turtle. As a result, it is the recommendation to use the dive profile for the green turtle depicted in figure 4 as a surrogate for the Kemp's ridley. Green turtles inhabit similar developmental habitats in the Gulf of Mexico and Florida waters as juvenile and adult Kemp's ridley turtles. Furthermore, green turtles are a relatively shallow diving species, similar to the Kemp's ridley. Additional behavior variables for the Kemp's ridley turtle recorded in the available literature are presented in table 111.

Table 111. Movement Behavior Variables from the Available Literature

Location	Variable	Value	Reference
Atlantic & Gulf of Mexico	Travel Rate (km/hr)	0.7 to 1.3 km/hr	Renaud (1995a)
Georgia to FL		0.28 +/- 0.22 km/hr	Gitschlag (1996)
Cedar Keys, FL		0.427 +/- 0.331 km/hr	Schmid et al. (2002)
Atlantic & Gulf of Mexico	Mean Dive/Submergence Duration (min)	33.7 +/- 2.25 min	Renaud (1995a)
Georgia to Florida		38.03 min	Gitschlag (1996)
Lavaca & Matagorda Bays, Texas		6.3 +/- 0.2 min	Renaud and Williams (1997)
Cedar Keys, FL		8.4 +/- 6.4 min	Schmid et al.(2002)
N. Padre & Mustang Islands, Texas		5.4 +/- 3.8 min	Shaver and Rubio (2007)
Atlantic & Gulf of Mexico	Percentage of Time Submerged	89 %	Renaud (1995a)
Georgia to Florida		94-95%	Gitschlag (1996)
Lavaca & Matagorda Bays, Texas		93.2 %	Renaud and Williams (1997)
Cedar Keys, FL		95.7 to 97 %	Schmid et al. (2002)
N. Padre & Mustang Islands, Texas		94%	Shaver and Rubio (2007)
Atlantic & Gulf of Mexico	Max Dive Duration (min)	280.9 min	Renaud (1995a)
Georgia to Florida		217 min	Gitschlag (1996)
Tamulipas, Mexico		22.1 min	Sasso and Witzell (2006)
Georgia to Florida	Surfacing Time	Average: 87sec	Gitschlag (1996)
Lavaca & Matagorda Bays, Texas		27.4 +/- 0.2 sec	Renaud and Williams (1997)
Cedar Keys, FL		18 +/- 15 sec	Schmid et al. (2002)
Tamulipas, Mexico		21.3 +/- 16.4 sec	Sasso and Witzell (2006)
Atlantic & Gulf of Mexico	Percent of Time at Surface	11%	Renaud (1995a)
Lavaca & Matagorda Bays, Texas		6.8 %	Renaud and Williams (1997)

<u>General Dive Behavior:</u>

In shallow summer foraging waters of the Atlantic, juveniles remained submerged during the day, generally feeding on the bottom (Morreale and Standora, 1998). Sasso and Witzell (2006) reported longer dives at night than during the day for this species. Dive times range from a few seconds to a maximum of 167 min with routine dives lasting between 16.7 and 33.8 min (Mendonça and Pritchard, 1986; Renaud, 1995b). Submergence time varies seasonally; dives are longest during the winter (greater than 30 min), and 15 min the remainder of the year (Renaud and Williams, 2005). Over a 12-hr period, Kemp's ridleys spend as long as 96% of their time submerged (Byles, 1989; Gitschlag, 1996; Renaud and Williams, 2005; Sasso and Witzell, 2006). In one study, mean surface duration was 18 sec, while submergence duration was 8.4 min (Schmid et al., 2002).

2.5.4.2.4 Caretta caretta, Loggerhead 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).

The general life-history model for this species is as follows: hatchlings travel to oceanic habitats, often occurring in Sargassum drift lines (Carr, 1986,1987; Witherington and Hirama, 2006). When juveniles reach sizes between 40 cm and 60 cm carapace length (about 14 years old), some individuals begin to recruit to the neritic zone (benthic habitat in shallow coastal waters) close to their natal area, while others remain in the oceanic habitat or move back and forth between the two (Musick and Limpus, 1997; Laurent et al., 1998). Turtles either may utilize the same neritic developmental habitat all through maturation, or they may move among different areas and finally settle in an adult foraging habitat. At sexual maturity (about 30 years old), adults switch from subadult to adult neritic foraging habitats (Musick and Limpus, 1997; Godley et al., 2003). Coral reefs, rocky places, and ship wrecks are often used as feeding areas. The turtles here are active and feed primarily on the bottom (epibenthic/demersal), though prey is also captured throughout the water column (Bjorndal, 2003; Bolten, 2003). The neritic zone not only provides crucial foraging habitat, but can also provide inter-nesting and overwintering habitat. In direct contrast with the accepted life-history model for this species, Hawkes et al. (2006) recently reported that tagging work at the Cape Verde Islands (Africa) revealed two distinct adult foraging strategies that appear to be linked to body size. The larger turtles foraged in coastal waters whereas smaller individuals foraged oceanically.

<u>Atlantic:</u>

In the western north Atlantic, the overwhelming majority of loggerhead nesting is concentrated along the coasts of the United States from North Carolina through Florida. Additional important nesting beaches are found along the eastern Yucatan peninsula, in the eastern Bahamas, the southwestern coast of Cuba, and along the coasts of Central America, Columbiam Venezuela, and the eastern Caribbean islands. In the western south Atlantic, loggerheads nest in significant numbers only in Brazil (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007c). In the eastern Atlantic, loggerheads nest in the Cape Verde Islands and along the West African coast.

Loggerheads seem generally restricted to waters of the North Atlantic Ocean south of 38° N, with mean sea surface temperatures around 22.2°C. Loggerhead turtles can be found along the U.S. Atlantic coast from Cape Cod to the Florida Keys during any season. They are most abundance in late spring through early fall which coincides with primary nesting season from FL to VA. The South Florida nesting sub-population is the largest nesting aggregation in U.S. jurisdiction. A small amount of scattered nesting occurs along the Panhandle and in the Gulf of Mexico states. Estuarine waters, including areas such as Long Island Sound, Chesapeake Bay, Pamlico and Core Sounds, Mosquito and Indian River Lagoons, Biscayne Bay, Florida Bay, and number embayments in the Gulf of Mexico comprise important inshore habitat. In the Gulf of Mexico, the Chandeleur Sound, Mobile Bay, Escambia Bay, and Tampa Bay likely serve as important developmental habitats for late juvenile loggerheads (Lohoefener et al., 1990; Davis et al., 2000b). In early spring, juvenile loggerheads over-wintering in southeastern U.S. waters begin to migrate north to developmental feeding habitats (Morreale and Standora, 2005). Juvenile loggerheads are also known to inhabit offshore waters in the Gulf of Mexico where they are often associated with artificial reefs and oil platforms (Fritts et al., 1983; Davis et al., 2000b).

Pacific:

Loggerheads an be found throughout tropical to temperate waters in the Pacific, however, their breeding grounds include a restricted number of sites in North Pacific and South pacific waters. In the South Pacific Ocean, loggerhead nesting is almost exclusively restricted to eastern Australia and New Caledonia. In the North Pacific, loggerhead nesting is essentially restricted to Japan.

In the South Pacific, nesting individuals tagged on the coast of eastern Ausralia have been recorded foraging in New Caledonia, Queensland, New South Wales, Northern Territory, Solomon Islands, Papua New Guinea, and Indonesia (Limpus and Limpus, 2003). In the North Pacific, important post-nesting hotspots have been identified in the East China Sea (Balazs, 2006), while satellite tracking of juveniles loggerheads indicates the Kuroshio Extension Bifurcation Region to be an important pelagic juvenile hotspot (Polovina et al., 2006). Other important juvenile foraging locations have been identified off the coast of Baja California Sur, Mexico (Pitman, 1990; Peckham and Nichols, 2006). Foraging Pacific loggerheads are also known to migrate to Chile and Peru (Shigueto et al., 2008).

Dive Profile Information:

The loggerhead turtle is a Tier 2 species. Depth distribution data recorded in table 112 are from Arendt et al. (2009b and Howell et al. (2010), and are considered representative dive profiles for the Atlantic and Pacific Ocean, respectively.

The data recorded by Arendt et al. (2009b) are an average of data from five male loggerhead turtles satellite tagged after their capture during trawl surveys in Cape Canaveral, FL. The turtles were tracked for an average of 144 days with a range of 7 to 366 days of recordings. Figure 5 illustrates the geographic extent of the study. The data recorded in Howell et al. (2010) are an average of data from 14 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. Figure 6 illustrates the geographic extent of the study.

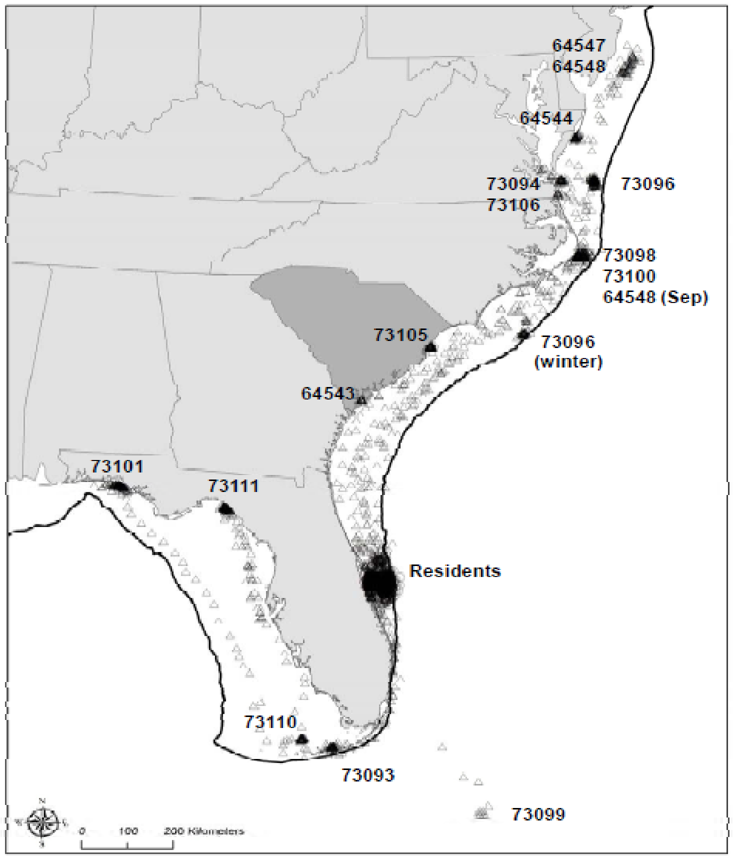

Figure 5. Movements of Loggerhead Turtles Tracked During 2007 Along the Southeast U.S. Coast (Arendt et al., 2009a)

Table 112. Percent of Time at Depth for Loggerheads in the Atlantic (Arendt et al., 2009a)

Depth Bin (m)	Percentage of Time Diving to each Depth Range					
	ID73093	ID73094	ID73095	ID 73096	ID73097	Average
Surface	40.0	8.0	11.8	19.4	84.5	32.739
0-5 m	51.6	24.8	2.2	27.7	2.1	21.667
6-10 m	3.2	15.2	1.0	10.3	1.7	6.274
11-15 m	5.2	36.9	7.6	6.0	7.7	12.675
16-20 m	0.0	9.9	4.1	2.1	2.1	3.664
21-25 m	0.0	1.1	23.7	1.5	0.7	5.397
26-50 m	0.0	3.1	49.0	32.5	0.3	16.968
51-75 m	0.0	0.6	0.0	0.5	0.3	0.280
76-100 m	0.0	0.4	0.2	0.0	0.3	0.167
101-127 m	0.0	0.0	0.4	0.0	0.4	0.170

Table 113. Movement Behavior Variables from (Arendt et al., 2009a)

Location	Variable	Value	Reference
U.S. East Coast & Gulf of Mexico	Max Dive Depth (m)	< 127 m	Arendt et al. (2009a)
	Percent Time at the Surface	32.7	

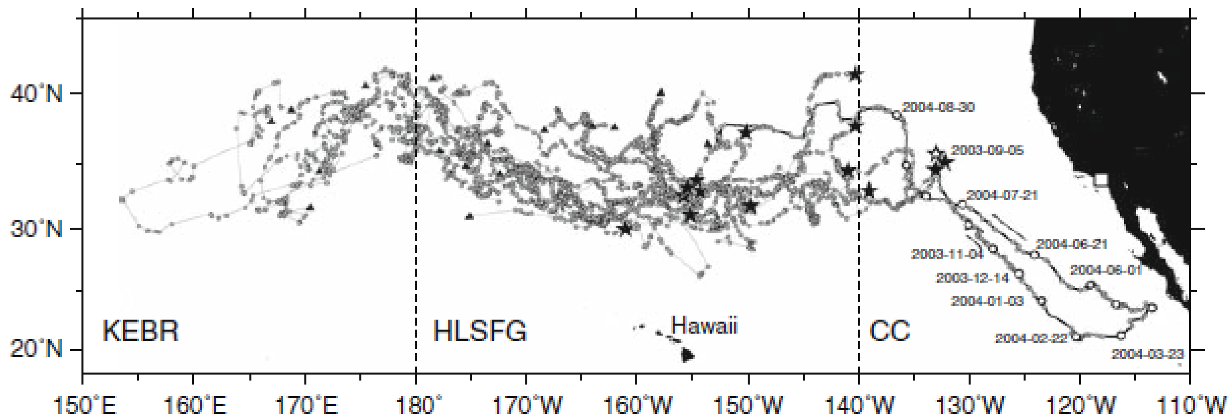

Figure 6. Movements of Loggerhead Turtles Tracked Between 2002–2004 in the North Pacific Ocean (Howell et al., 2010)

Table 114. Percent of Time at Depth for the Loggerhead Turtle in the Pacific (Howell et al. 2010)

Depth (m)[a]	Percentage of Time at Depth	Depth (m)[a]	Percentage 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

[a] 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 a female turtle tagged off the coast of Japan (Sakamoto et al., 1990). This value was used to represent the maximum depth for the dive distribution profile.

Table 115. Movement Behavior Variables from Howell et al. (2010)

Location	Variable	Value	Reference
North Pacific Ocean	Max Dive Depth (m)	150 + (Tags unable to define exact depth)	Howell et al. (2010)
	Average Dive Duration (min)	< 2 min	
	Max Dive Duration (min)	240 min	
	Percent Time at the Surface	19.25	

General Dive Behavior Information:

On average, loggerhead turtles spend over 90% of their time underwater (Byles, 1988; Renaud and Carpenter, 1994; Narazaki et al., 2006). Loggerheads tend to remain at depths shallower than 100 m (Houghton et al., 2002; Polovina et al., 2003a; Hawkes et al., 2006; Narazaki et al., 2006; McClellan et al., 2007). Routine dive depths are typically shallower than 30 m (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). Routine dives typically can last from 4 to 120 minutes (Byles, 1988; Sakamoto et al., 1990; Renaud and Carpenter, 1994; Bentivegna et al., 2003; Dodd and Byles, 2003).

2.5.4.2.5 Lepidochelys olivacea, Olive Ridley Turtle. Olive ridleys are globally distributed and have a large range in tropical and subtropical regions of the Pacific, Indian, and South Atlantic oceans, and are generally found between 40º N and 40º S. Most olive ridley turtles lead a primarily pelagic existence. The Pacific population migrates throughout the Pacific from their nesting grounds in Mexico and Central America to the North Pacific (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007d). The olive ridley is the most abundant sea turtle in the open ocean waters of the eastern tropical Pacific Ocean (Pitman, 1990).

Atlantic:

In the South Atlantic, they are found along the Atlantic coasts of West Africa and South America. Nesting occurs in Suriname and French Guiana, though nesting populations are very small relative to those on Pacific and Indian beaches, with annual nest counts of 150–300 and 1,444–1,844, respectively (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998d). The species also nests in moderate numbers in tropical West Africa and in relatively small numbers in southern Asia.

While olive ridleys are primarily a pelagic species and are known to migrate great distances in the Pacific, there are few pelagic records of this species in the Atlantic, and little is known about their migration patterns (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007d). A few reports of olive ridleys in the North Atlantic, as far north as the Grand Banks, indicate that the species does traverse the entire Atlantic Ocean, although their occurrence north of the equator is believed rare (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007d). While they have been documented in Puerto Rico, the Dominican Republic, and Cuba (Foley et al., 2003), they are rarely found in the Caribbean Sea. The olive ridley turtle is not expected to occur within the Atlantic Ocean offshore of the U.S. Atlantic coast, with no sightings and only three documented strandings of olive ridleys in the Gulf of Mexico (Foley et al., 2003). Habitat preferences of the olive ridley are similar to those of the leatherback turtle (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998d) in that they both occupy oceanic habitats and nest primarily on the Pacific shores of the American tropics and in the Atlantic along the shores of Guiana, Suriname, and Guyana (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998d).

Pacific:

In the eastern Pacific, the largest nesting concentrations occur in southern Mexico and northern Costa Rica, with stragglers nesting as far north as southern Baja California (Fritts et al., 1982)and as far south as Peru (Brown and Brown, 1982). Olive ridleys nest throughout the year in the eastern Pacific with peak months, including major arribadas, occurring from September through December (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998d). There is no known nesting on the U.S. west coast.

The Pacific population migrates throughout the Pacific, from their nesting grounds in Mexico and Central America to the North Pacific (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 2007d). Post-nesting migration routes of olive ridleys tracked via satellite from Costa Rica traversed thousands of kilometers of deep ocean waters from Mexico to Peru, and more 3,000 km out into the central Pacific (Plotkin et al., 1994). Tagged turtles nesting in Costa Rica were recovered as far south as Peru, as far north as Oaxaca, Mexico, and offshore to a distance of 2,000 km (Cornelius and Robinson 1986a; National Marine Fisheries Service et al., 1998). Neither males nor females migrate to one specific foraging area, but exhibit a nomadic movement pattern and occupy a series of feeding areas in the oceanic waters (Plotkin et al., 1994). Data collected during tuna fishing cruises from Baja California to Ecuador and from the coast to almost 150º W indicated that the two most important areas in the Pacific for the olive ridley are the central American coast and the nursery/feeding area off Colombia and Ecuador, where both adults (mostly females) and juveniles are often seen (National Marine Fisheries Service (NMFS) and United States Fish and Wildlife Service (USFWS), 1998d).

At-sea occurrences in the U.S. and waters under U.S. jurisdiction are limited to the west coast of the continental U.S. (Stinson, 1984a) and Hawaii. Available information suggests that olive ridleys traverse through the oceanic waters surrounding the Hawaiian Islands during foraging and developmental migrations (Nitta and Henderson, 1993).

Dive Depth Profile:

The olive ridley turtle is a Tier 2 species. Depth distribution data recorded in table 116 is from Polovina et al. (2003a and Polovina et al. (2004). The data recorded in this study are the average of data from two satellite tracked olive ridley turtles. The turtles were tagged after being caught in commercial long-line fishing gear southwest of the Hawaiian Islands. The turtles were tracked for a period of 3.4 and 0.8 months, respectively. Figure 7 illustrates the geographic extent of the study.

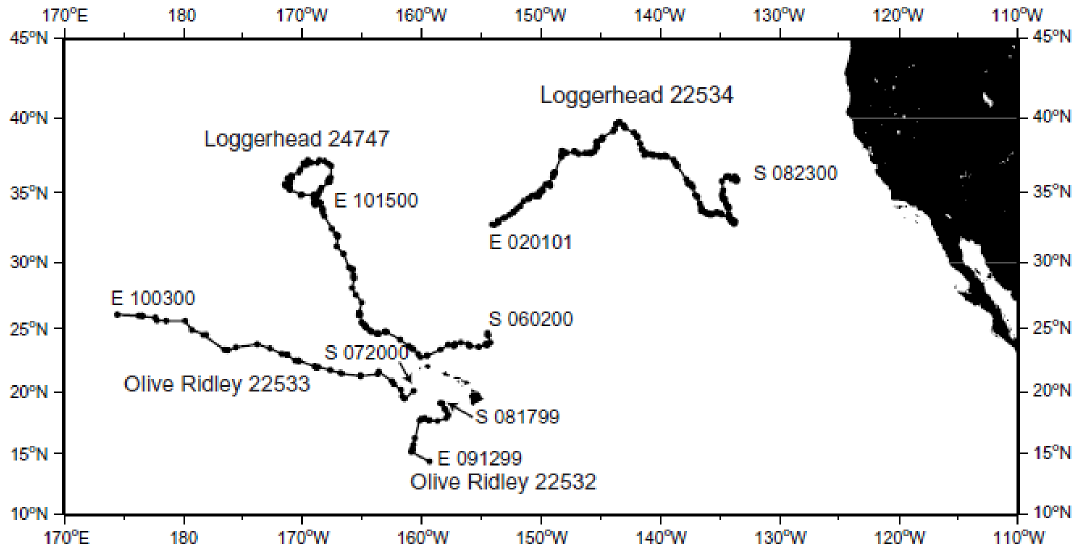

Figure 7. Movements of Olive Ridleys (Polovina et al., 2003b; Polovina et al., 2004)

Table 116. Percent of Time at Depth for the Olive Ridley Turtle (Polovina et al. 2003b; Polovina et al., 2004)

Depth (m)[a]	Percentage of Time at Depth
0-1	20.00
1- 10	5.00
11-20	8.50
21-30	14.00
31-40	13.50
41-50	10.00
51-60	7.00
61-70	5.50
71-80	4.50

Depth (m)[a]	Percentage of Time at Depth
81-90	3.00
91-100	2.50
101-110	1.50
111-120	1.00
121-130	1.50
131-140	0.50
141-150	1.00
151 - 288	1.00

[a] Technical limitations of the tags used in the (Polovina et al., 2003b; Polovina et al., 2004) studies 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 olive ridley turtle is 288 m, recorded from an adult turtle tagged after being incidentally caught in long-line fishing gear off the Pacific coast of Costa Rica (Swimmer et al., 2006, table 1). This value was used to represent the maximum depth for the dive distribution profile.

Table 117. Movement Behavior Variables from Polovina et al. (2003b) and Polovina et al. (2004)

Location	Variable	Value	Reference
North Pacific Ocean	Distance Traveled (km)	7,283 km	Polovina et al. (2004)
	Speed (m/s)	In the North Equatorial Current (NEC): 0.72 +/- 12 m/s Outside of the North Equatorial Current (NEC): 0.48 +/- 6 m/s	Polovina et al. (2004)
	Max Dive Depth (m)	254 m	Polovina et al. (2003b)
	Percent Time at the Surface	20%	Polovina et al. (2003b)

General Dive Behavior Information:

Olive ridley turtles can dive and feed at considerable depths (80–300 m) (Eckert, 1995), although only about 5–10% of their time is spent at depths greater than 100 m (Eckert et al., 1986; Polovina et al., 2003a). In the eastern tropical Pacific Ocean, at least 25% of their total dive time is spent in the permanent thermocline located at 20–100 m (Parker et al., 2003). Olive ridleys spend considerable time at the surface basking, presumably in an effort to speed their metabolism and digestion after a deep dive (Spotila, 2004). In the open ocean of the eastern Pacific, olive ridley turtles are often seen near flotsam, possibly feeding on associated fish and invertebrates (Pitman, 1992). In the North Pacific Ocean, two olive ridleys tagged with satellite-linked depth recorders spent about 20% of their time in the top meter; 70% of the dives were no deeper than 50 m (Polovina et al., 2003a). The average dive lengths for adult females and males are reported to be 54.3 min and 28.5 min, respectively (Plotkin, as cited in Lutcavage and Lutz (1997)). In a separate study (McMahon et al., 2007), olive ridleys exhibited exceptionally long dive durations (greater than 2 hr) allowing this species to exploit deeper benthic prey.

2.6 CONCLUSIONS

The recommended static depth distributions are provided for 68 marine mammal species occurring within the AFTT and HSTT Study Areas. These distributions, especially those that rely on surrogates, should be updated routinely as new data become available. Also, for most species, only a single depth distribution is presented. Ideally, each species should have multiple distributions available, depending on the behavior and age/sex class of the animals being modeled, as well as the geographic location and season in which the simulation occurs. More detailed depth distribution data will permit improved realism for the scenarios being modeled.

3. GROUP SIZE INFORMATION FOR ODONTOCETES OCCURRING IN THE EASTERN NORTH AND CENTRAL PACIFIC OCEAN

3.1 INTRODUCTION

Many speices of Odontocetes occur in groups ranging in size from two to hundreds or thousands of individuals. To more accurately represent the non-uniform distribution of odontocetes, group size data are needed. Estimates of odontocete group sizes are required for use in NAEMO for the Eastern North and Central Pacific Ocean covering portions of the previously defined 3rd Fleet Areas of Responsibility (AOR) (figure 8).

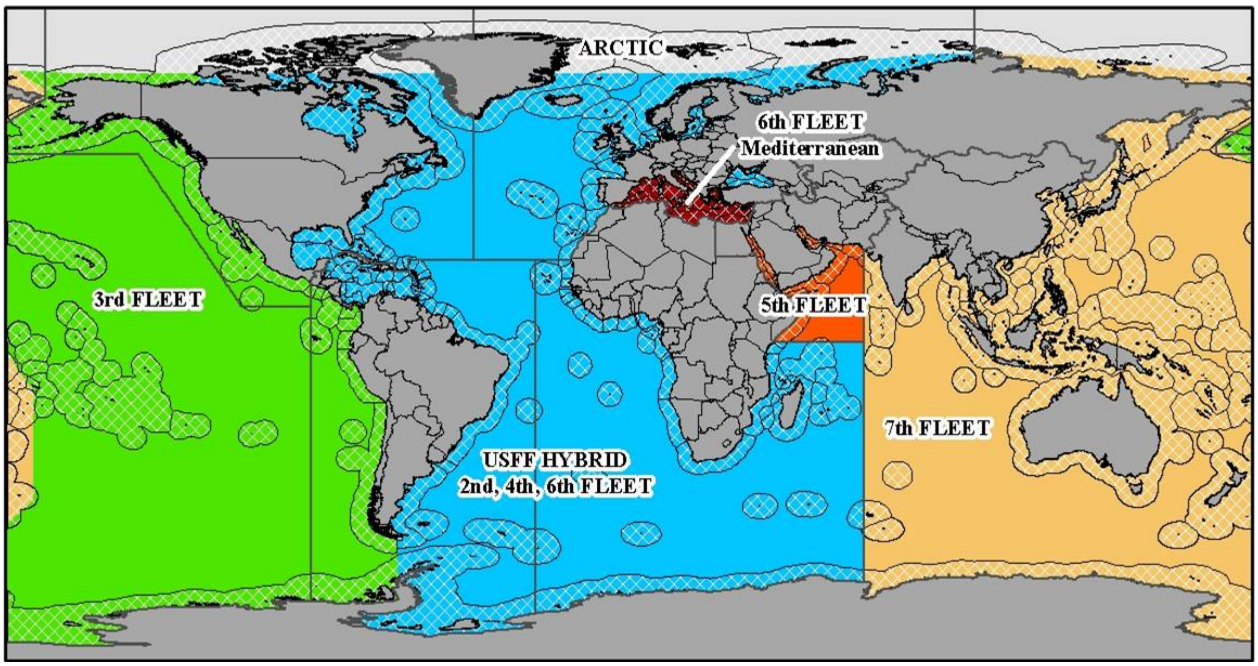

Figure 8. Numbered Fleet Areas of Responsibility

3.2 SPECIES TO MODEL AS GROUPS

Modeling using NAEMO includes marine mammal species that occur from the U.S. coastal waters up to a Foreign Exclusive Economic Zone. In the Pacific Ocean, portions of the Eastern North and Central Pacific Ocean were the only areas for which marine mammal group size was researched. This includes an area from the Gulf of Alaska south to the 20° S latitude line, bounded by the North, Central, and South American coasts on the east and the 180° longitude meridian on the west (figure 9). Additionally, odontocetes are more likely to occur in large groups at sea than other types of marine mammals and are the only group for which group size data were gathered (Acevedo-Gutierrez, 2002). Therefore, group size for mysticetes, pinnipeds, and sirenians are not included in this document.

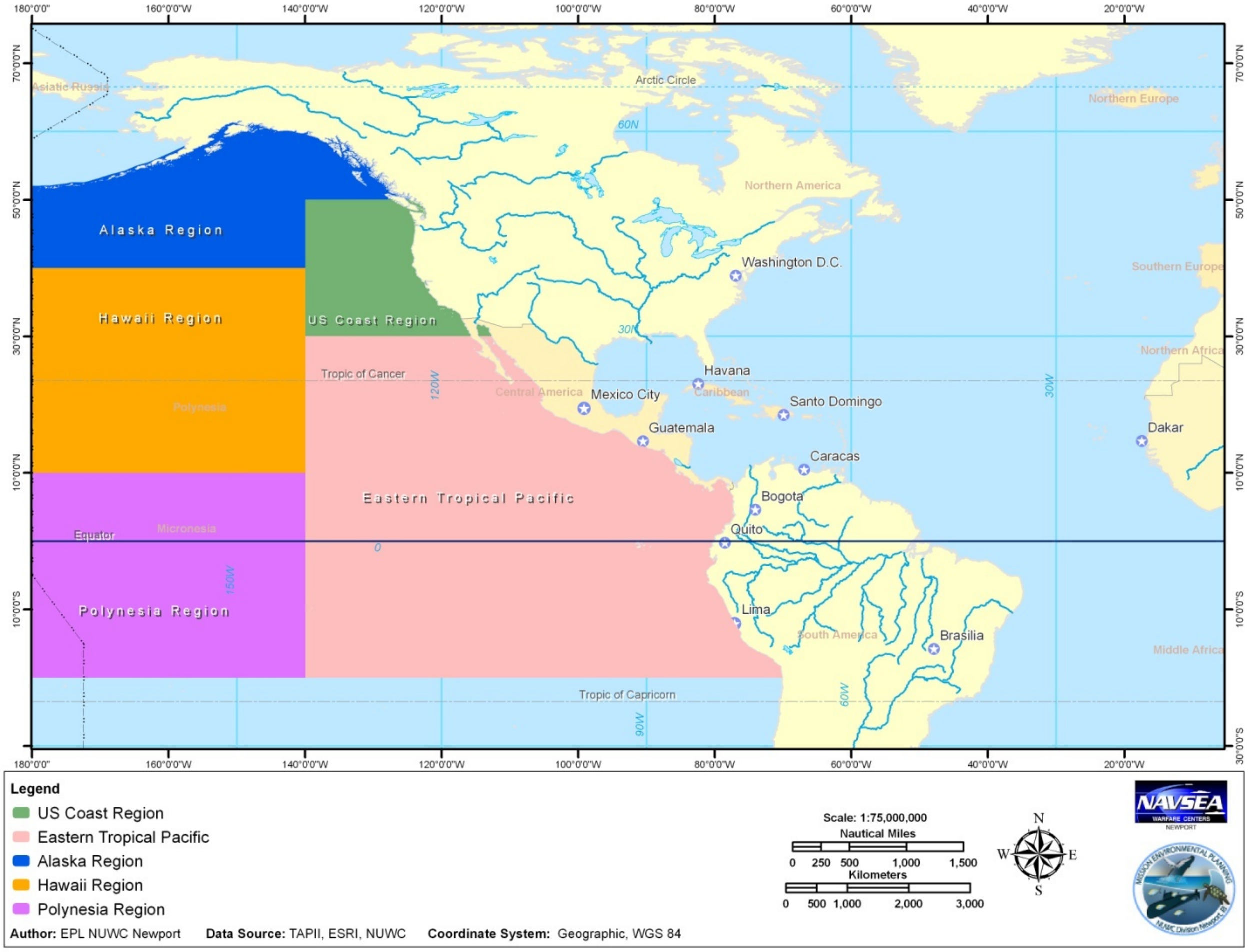

Figure 9. Eastern North and Central Pacific Areas Researched for Group Size Information

3.3 BEST AVAILABLE SCIENCE

A comprehensive and systematic review of relevant literature and data was conducted for completion of this white paper. Of the available published and unpublished literature, the following types of documents were utilized: journals, books, technical reports, cruise reports, theses, and dissertations.

Information was collected from the following sources to summarize group size information for all odontocetes that occur in the Eastern North and Central Pacific Ocean, excluding Foreign Eclusive Economic Zones (FEEZs):

- Marine Biological/Woods Hole Oceanographic Institution Library online databases: ScienceDirect, Aquatic Science and Fisheries Abstracts, GeoRef, Biological Sciences, and Web of Science.

- The internet, including various databases and related websites: International Union for Conservation of Nature and Natural Resources (IUCN), National Oceanic and Atmospheric Administration (NOAA), NMFS Regional Science Centers, and Google Scholar.

Keywords that were researched included combinations and permutations of the following: common names, genus and species, family names, group, group size, dispersion, dolphin group dispersion, live sighting, cetacean distribution, marine mammal distribution, cruise report, Pacific Ocean, Hawaii, Alaska, Polynesia, and Eastern Tropical Pacific.

3.4 GROUP SIZE INFORMATION

Data from all relevant sources were pooled based on individual species occurring at the following five locations: Alaska Region, U.S. Coast Region, Hawaii Region, Eastern Tropical Pacific, and Polynesia Region (figure 9). The average of all mean group sizes reported by the literature for each species at the five locations were determined, as well as SDs associated with these means. If a range of means was given in any particular study, the maximum value was used to represent the mean. Minimum and maximum group sizes were also determined for each species at each location. In some instances, data were lacking, therefore, data from multiple areas were combined or the geographically closest data were applied. For example, group size data for the false killer whale (*Pseudorca crassidens*) were lacking in the U.S. Coast Region, thus, data from the Eastern Tropical Pacific were used as surrogates. Additionally, pygmy and dwarf sperm whales (*Kogia breviceps* and *K. simus*, respectively) often are indistinguishable at sea. Subsequently, data for these species were combined, and the species herein are referred to as *Kogia* spp.

Table 118, table 119, and table 120 provide group size information including means, SDs, and ranges for all odontocete species that occur in the Alaska, U.S. coast and Hawaii Regions, and Eastern Tropical Pacific and Polynesia Region, respectively.

Table 118. Group Size Information (Mean Number of Animals, SDs, and Ranges) for Odontocete Species that Occur in the Alaska Region of the Pacific Ocean

Common and Scientific Names	Alaska Region			References
	mean	SD	range	
Sperm whale *Physeter macrocephalus*	1.50	1.92	1-3	(Perrin et al. 2002; Wade et al. 2003; Sekiguchi et al. 2005; Zerbini 2010)
Beluga whale *Delphinapterus leucas*	45.32	38.78	1-731	(Frost et al. 1993; Hobbs et al. 2000; Laidre et al. 2000; Moore and DeMaster 2000; Perrin et al. 2002; Rugh et al. 2004)
False killer whale [a] *Pseudorca crassidens*	30.15	17.18	20-200	(Breese and Tershy 1993; Perrin et al. 2002)
Killer whale *Orcinus orca*	14.78	15.99	1-140	(Stewart et al. 1987; Wade et al. 2003; Rugh et al. 2005; Sekiguchi et al. 2005; Zerbini et al. 2007; Dahlheim et al. 2009; Rone et al. 2010; Zerbini 2010)
Northern right whale dolphin [a] *Lissodelphis borealis*	44.01	48.43	2-2000	(Smith et al. 1986; Shane 1994; Forney et al. 1995; Laake et al. 1998; Carretta 2001; Perrin et al. 2002; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)
Pacific white-sided dolphin *Lagenorhynchus obliquidens*	42.91	32.83	6-6000	(Perrin et al. 2002; Wade et al. 2003; Sekiguchi et al. 2005; Dahlheim et al. 2009; Rone et al. 2010; Zerbini 2010)
Risso's dolphin [a] *Grampus griseus*	24.81	27.93	1-220	(Leatherwood et al. 1980; Smith et al. 1986; Shane 1994; Forney et al. 1995; Laake et al. 1998; Carretta et al. 2000; Bearzi 2003; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Oswald et al. 2008; Carretta et al. 2009; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)
Short-finned pilot whale [a] *Globicephala macrorhynchus*	25.80	7.52	18-33	(National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Jefferson et al. 2008; Hildebrand 2009)
Dall's porpoise *Phocoenoides dalli*	3.55	2.40	1-25	(Stewart et al. 1987; Perrin et al. 2002; Wade et al. 2003; Rugh et al. 2005; Sekiguchi et al. 2005; Dahlheim et al. 2009; Rone et al. 2010; Zerbini 2010)
Harbor porpoise *Phocoena phocoena*	1.82	0.98	1-7	(Stewart et al. 1987; Perrin et al. 2002; Wade et al. 2003; Rugh et al. 2005; Sekiguchi et al. 2005; Dahlheim et al. 2009; Rone et al. 2010; Zerbini 2010)
Baird's beaked whale *Berardius bairdii*	10.17	10.78	1-100	(Perrin et al. 2002; Wade et al. 2003; MacLeod and D'Amico 2006; Zerbini 2010)
Cuvier's beaked whale [a] *Ziphius cavirostris*	2.41	0.53	1-15	(Smith et al. 1986; Barlow 1995; Perrin et al. 2002; Appler et al. 2004; MacLeod and D'Amico 2006; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Falcone et al. 2009; Simon Sanctuary Integrated Monitoring Network 2010)
Stejneger's beaked whale *Mesoplodon stejnegeri*	4.71	3.84	1-15	(Loughlin et al. 1982; Loughlin and Perez 1985)

[a] All U.S. Coast Region data were used due to paucity of data for the Alaska region.

Table 119. Group Size Information (Mean Number of Animals, SDs, and Ranges) for Odontocete Species that Occur in the U.S. Coast and Hawaii Regions

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Sperm whale *Physeter macrocephalus*	7.01	8.47	1-120	(Smith et al. 1986; Forney et al. 1995; Perrin et al. 2002; Appler et al. 2004; Barlow and Taylor 2005; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)	5.52	4.78	1-120	(Mobley et al. 2000; Perrin et al. 2002; Baird et al. 2003b; Barlow 2006,2007; Reeves et al. 2009)
Dwarf and pygmy sperm whales *Kogia* spp.	1.22	0.25	1-10	(Smith et al. 1986; Barlow 1995; Willis and Baird 1998; Appler et al. 2004; Barlow and Forney 2007)	1.75	0.52	1-10	(Willis and Baird 1998; Perrin et al. 2002; Baird et al. 2003b; Baird 2005; Barlow 2006,2007)
Bottlenose dolphin *Tursiops truncatus*	19.46	23.59	1-139	(Smith et al. 1986; Hansen 1990; Breese and Tershy 1993; Shane 1994; Forney et al. 1995; Carretta et al. 1998; Defran and Weller 1999; Marsh et al. 1999; Carretta et al. 2000; Appler et al. 2004; Bearzi 2005; National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008)	6.02	2.16	1-40	(Mobley et al. 2000; Baird et al. 2003b; Barlow 2006,2007; Baird et al. 2009; Reeves et al. 2009)
False killer whale *Pseudorca crassidens*	30.15	17.18	20-200	(Breese and Tershy 1993; Perrin et al. 2002)	12.72	9.83	2-470	(Mobley et al. 2000; Perrin et al. 2002; Barlow et al. 2004; Barlow 2006,2007; Reeves et al. 2009)

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Fraser's dolphin [a] *Lagenodelphis hosei*	185.13	178.6	23-1500	(Holt and Jackson 1987; Kinzey et al. 2000; Jackson et al. 2004; Barlow 2006; Jackson et al. 2008)	219.70	146.71	47-1500	(Perrin et al. 2002; Barlow et al. 2004; Barlow 2006,2007)
Killer whale *Orcinus orca*	8.63	7.25	1-89	(Smith et al. 1986; Breese and Tershy 1993; Rus Hoelzel 1993; Baird and Dill 1995; Laake et al. 1998; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Parsons et al. 2009; Williams and Thomas 2009; Simon Sanctuary Integrated Monitoring Network 2010)	4.20	2.20	2-7	(Baird et al. 2003b; Barlow 2006,2007)
Long-beaked common dolphin *Delphinus capensis*	156.26	126.45	8-315	(Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Forney 2007; Jefferson et al. 2008; Oswald et al. 2008; Hildebrand 2009)	N/A	N/A	N/A	N/A
Melon-headed whale *Peponocephala electra*	N/A	N/A	N/A	N/A	144.15	139.46	13-400	(Mobley et al. 2000; Perrin et al. 2002; Baird et al. 2003b; Barlow 2006,2007; Brownell Jr. et al. 2009; Reeves et al. 2009)
Northern right whale dolphin *Lissodelphis borealis*	44.01	48.43	2-2000	(Smith et al. 1986; Shane 1994; Forney et al. 1995; Laake et al. 1998; Carretta et al. 2000; Perrin et al. 2002; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)	N/A	N/A	N/A	N/A

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Pacific white-sided dolphin *Lagenorhynchus obliquidens*	49.54	55.74	1-6000	(Smith et al. 1986; Stacey and Baird 1991; Shane 1994; Forney et al. 1995; Laake et al. 1998; Carretta et al. 2000; Morton 2000; Perrin et al. 2002; Bearzi 2003; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)	N/A	N/A	N/A	N/A
Pantropical spotted dolphin [b] *Stenella attenuata*	61.20	19.45	4-2400	(Mobley et al. 2000; Baird et al. 2001; Perrin et al. 2002; Baird et al. 2003b; Barlow 2006,2007; Reeves et al. 2009)	61.20	19.45	4-2400	(Mobley et al. 2000; Baird et al. 2001; Perrin et al. 2002; Baird et al. 2003b; Barlow 2006,2007; Reeves et al. 2009)
Pygmy killer whale *Feresa attenuata*	N/A	N/A	N/A	N/A	10.52	5.00	3-15	(Baird et al. 2003b; Barlow et al. 2004; Barlow 2006,2007; Reeves et al. 2009)
Risso's dolphin *Grampus griseus*	24.81	27.93	1-220	(Leatherwood et al. 1980; Smith et al. 1986; Shane 1994; Forney et al. 1995; Laake et al. 1998; Carretta et al. 2000; Bearzi 2003; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Hildebrand 2009; Simon Sanctuary Integrated Monitoring Network 2010)	8.83	7.28	1-15.4	(Mobley et al. 2000; Barlow 2006,2007)
Rough-toothed dolphin [b]	9.08	4.75	2-90	(Mobley et al. 2000; Baird et al. 2003b; Barlow 2006,2007;	9.08	4.75	2-90	(Mobley et al. 2000; Baird et al. 2003b; Barlow

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Steno bredanensis				Baird et al. 2008a; Reeves et al. 2009)				2006,2007; Baird et al. 2008a; Reeves et al. 2009)
Short-beaked common dolphin *Delphinus delphis*	140.38	92.57	10-10,000	(Carretta et al. 2000; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Jefferson et al. 2008; Oswald et al. 2008; Hildebrand 2009)	32.80	N/A	32.8	(Barlow 2007)
Short-finned pilot whale *Globicephala macrorhynchus*	25.80	7.52	18-33	(National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Jefferson et al. 2008; Hildebrand 2009)	16.36	7.82	8-32	(Mobley et al. 2000; Baird et al. 2003b; Barlow 2006,2007; Reeves et al. 2009)
Spinner dolphin *Stenella longirostris*	N/A	N/A	N/A	N/A	58.00	69.16	1-260	(Mobley et al. 2000; Baird et al. 2003b; Lammers 2004; Karczmarski et al. 2005; Barlow 2006,2007; Reeves et al. 2009)
Striped dolphin *Stenella coeruleoalba*	38.98	19.99	3-55	(Smith et al. 1986; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008)	29.98	13.32	17-45	(Mobley et al. 2000; Baird et al. 2003b; Barlow 2006,2007)
Dall's porpoise *Phocoenoides dalli*	3.78	1.16	2-15	(Smith et al. 1986; Shane 1994; Barlow 1995; Forney et al. 1995; Laake et al. 1998; Carretta et al. 2000; Perrin et al. 2002; Bearzi 2003; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Oswald et al. 2008; Simon Sanctuary Integrated Monitoring Network 2010)	N/A	N/A	N/A	N/A

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Harbor porpoise *Phocoena phocoena*	2.02	1.05	1-6	(Barlow and Forney 1994; Barlow 1995; Forney et al. 1995; Perrin et al. 2002; Appler et al. 2004; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Forney 2007; Oswald et al. 2008; Simon Sanctuary Integrated Monitoring Network 2010)	N/A	N/A	N/A	N/A
Baird's beaked whale *Berardius bairdii*	6.40	2.43	1-100	(Smith et al. 1986; Balcomb 1989; Perrin et al. 2002; Appler et al. 2004; MacLeod and D'Amico 2006; National Oceanic and Atmospheric Administration (NOAA) 2006a; Barlow and Forney 2007; Forney 2007)	N/A	N/A	N/A	N/A
Blainville's beaked whale *Mesoplodon densirostris*	2.11	0.63	1-8	(Forney et al. 1995; MacLeod and D'Amico 2006; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Simon Sanctuary Integrated Monitoring Network 2010)	2.84	0.96	1-9	(Mobley et al. 2000; Baird et al. 2003b; Barlow 2006; MacLeod and D'Amico 2006; Barlow 2007; McSweeney et al. 2007)
Cuvier's beaked whale *Ziphius cavirostris*	2.41	0.53	1-15	(Smith et al. 1986; Barlow 1995; Carretta et al. 2000; Perrin et al. 2002; Appler et al. 2004; MacLeod and D'Amico 2006; National Oceanic and Atmospheric Administration (NOAA) 2006b,a; Barlow and Forney 2007; Forney 2007; Falcone et al. 2009; Simon Sanctuary Integrated Monitoring Network 2010)	2.30	0.51	1-15	(Mobley et al. 2000; Perrin et al. 2002; Barlow 2006; MacLeod and D'Amico 2006; Barlow 2007; Falcone et al. 2009)

Common and Scientific Names	U.S. Coast Region			References	Hawaii Region			References
	mean	SD	range		mean	SD	range	
Ginkgo-toothed beaked whale [c] *Mesoplodon gingkodens*	6.00	--	1-10	(Pitman 2002b)	6.00	--	1-10	(Pitman 2002b)
Hubb's beaked whale [c] *Mesoplodon carlhubbsi*	6.00	--	1-10	(Pitman 2002b)	N/A	N/A	N/A	N/A
Longman's beaked whale [b] *Indopacetus pacificus*	11.40	8.33	1-100	(Barlow et al. 2004; Barlow 2006; MacLeod and D'Amico 2006; Barlow 2007)	11.40	8.33	1-100	(Barlow et al. 2004; Barlow 2006; MacLeod and D'Amico 2006; Barlow 2007)
Perrin's beaked whale [c] *Mesoplodon perrini*	6.00	--	1-10	(Pitman 2002b)	N/A	N/A	N/A	N/A
Pygmy beaked whale [d] *Mesoplodon peruvianus*	1.40	0.53	1-2	(Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008)	1.40	0.53	1-2	(Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008)
Stejneger's beaked whale [c] *Mesoplodon stejnegeri*	6.00	--	1-10	(Pitman 2002b)	N/A	N/A	N/A	N/A

[a] All Eastern Tropical Pacific data were used due to paucity of data for the U.S. coast region.
[b] All Hawaii Region data were used due to paucity of data for the U.S. coast region.
[c] General Mesoplodont species data used due to paucity of data for this species.
[d] All Eastern Tropical Pacific data were used due to paucity of data for the U.S. coast region and Hawaii Region.

Table 120. Group Size Information (Mean Number of Animals, SDs, and Ranges) for Odontocete Species that Occur in the Eastern Tropical Pacific and Polynesia Region

Common and Scientific Names	Eastern Tropical Pacific			References	Polynesia Region			References
	mean	SD	range		mean	SD	range	
Sperm whale *Physeter macrocephalus*	5.50	1.08	4-120	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Richard et al. 1996; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Jackson et al. 2008)	6.95	8.41	1-120	(Gannier 2000; Perrin et al. 2002)
Dwarf and pygmy sperm whales *Kogia* spp.	1.49	0.36	1-10	(Holt and Jackson 1987; Wade and Gerrodette 1993; Mangeis and Gerrodette 1994; Au and Pitman 1998; Willis and Baird 1998; Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008)	2.00	NA	1-10	(Willis and Baird 1998; Gannier 2000)
Bottlenose dolphin *Tursiops truncatus*	29.01	16.94	6-10,000	(Holt and Jackson 1987; Scott and Chivers 1990; Van Waerebeek et al. 1990; Mangeis and Gerrodette 1994; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)	8.38	3.27	1-35	(Gannier 2000; Laran and Grannier 2001; Brasseur et al. 2002; Gannier 2002)
False killer whale [a] *Pseudorca crassidens*	14.80	6.80	2-100	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Ferguson et al. 2006; Jackson et al. 2008; Oswald et al. 2008)	14.80	6.80	2-100	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Ferguson et al. 2006; Jackson et al. 2008; Oswald et al. 2008)
Fraser's dolphin *Lagenodelphis hosei*	185.13	178.61	23-1500	(Holt and Jackson 1987; Kinzey et al. 2000; Jackson et al. 2004; Barlow 2006;	210.95	260.14	25-1500	(Gannier 2000; Barlow 2006)

Common and Scientific Names	Eastern Tropical Pacific			References	Polynesia Region			References
	mean	SD	range		mean	SD	range	
				Jackson et al. 2008)				
Killer whale [a] *Orcinus orca*	5.21	2.04	2-10	(Dahlheim et al. 1982; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Jackson et al. 2004; Ferguson et al. 2006; Jackson et al. 2008; Oswald et al. 2008)	5.21	2.04	2-10	(Dahlheim et al. 1982; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Jackson et al. 2004; Ferguson et al. 2006; Jackson et al. 2008; Oswald et al. 2008)
Long-beaked common dolphin *Delphinus capensis*	302.25	177.05	1-1298	(Mangeis and Gerrodette 1994; Kinzey et al. 2000; Jackson et al. 2004; Oswald et al. 2008)	NA	NA	NA	NA
Melon-headed whale *Peponocephala electra*	259.36	154.11	73-481	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Ferguson et al. 2006; Jackson et al. 2008)	355.02	375.88	30-900	(Gannier 2000; Laran and Grannier 2001; Gannier 2002; Perrin et al. 2002; Brownell Jr. et al. 2009)
Pacific white-sided dolphin *Lagenorhynchus obliquidens*	50.80	54.50	3-6000	(Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Ferguson et al. 2006)	NA	NA	NA	NA
Pantropical spotted dolphin *Stenella attenuata*	97.26	37.34	45-2400	(Au and Perryman 1985; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Perrin et al. 2002; Jackson et al. 2004; Gerrodette and Forcada 2005; Cubero-Pardo 2007; Jackson et al. 2008; Oswald et al. 2008)	19.75	17.18	2-2400	(Laran and Grannier 2001; Gannier 2002; Perrin et al. 2002)
Pygmy killer whale *Feresa attenuata*	31.17	20.46	14-70	(Baird et al. 2003b; Barlow et al. 2004; Barlow 2006,2007; Reeves et al. 2009)	10.52	5.00	3-15	(Baird et al. 2003b; Barlow et al. 2004; Barlow 2006,2007; Reeves et al. 2009)
Risso's dolphin *Grampus griseus*	13.94	4.49	2-79	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000;	4.00	NA	4	(Gannier 2000)

Common and Scientific Names	Eastern Tropical Pacific			References	Polynesia Region			References
	mean	SD	range		mean	SD	range	
				Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)				
Rough-toothed dolphin *Steno bredanensis*	10.50	2.26	1-34	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)	11.74	4.16	1-35	(Gannier 2000; Laran and Grannier 2001; Gannier 2002; Gannier and West 2005)
Short-beaked common dolphin *Delphinus delphis*	223.92	92.12	125-342	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)	NA	NA	NA	NA
Short-finned pilot whale *Globicephala macrorhynchus*	14.67	5.06	1-230	(Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)	23.17	10.54	9-35	(Gannier 2000; Laran and Grannier 2001; Gannier 2002)
Spinner dolphin *Stenella longirostris*	282.41	285.02	1-987	(Au and Perryman 1985; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Jackson et al. 2004; Gerrodette and Forcada 2005; Jackson et al. 2008; Oswald et al. 2008)	26.98	13.25	2-100	(Gannier 2000; Laran and Grannier 2001; Gannier 2002; Gannier and Petiau 2006)
Striped dolphin [a] *Stenella coeruleoalba*	58.01	12.91	44-82	(Au and Perryman 1985; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)	58.01	12.91	44-82	(Au and Perryman 1985; Holt and Jackson 1987; Mangeis and Gerrodette 1994; Jackson et al. 2004; Jackson et al. 2008; Oswald et al. 2008)
Baird's beaked whale *Berardius bairdii*	9.31	5.91	1-100	(Balcomb 1989; Mangeis and Gerrodette 1994; Perrin et al. 2002; Jackson et al. 2004; MacLeod and D'Amico 2006; Jackson et al. 2008)	NA	NA	NA	NA
Blainville's beaked whale *Mesoplodon densirostris*	2.50	1.41	1-8	(Mangeis and Gerrodette 1994; Kinzey et al. 2000;	3.25	0.35	1-8	(Gannier 2000; MacLeod and D'Amico 2006)

Common and Scientific Names	Eastern Tropical Pacific			References	Polynesia Region			References
	mean	SD	range		mean	SD	range	
				MacLeod and D'Amico 2006)				
Cuvier's beaked whale *Ziphius cavirostris*	2.08	0.36	1-15	(Holt and Jackson 1987; Mangeis and Gerrodette 1994; Kinzey et al. 2000; Perrin et al. 2002; MacLeod and D'Amico 2006; Jackson et al. 2008; Falcone et al. 2009)	2.20	0.17	1-15	(Gannier 2000; Perrin et al. 2002; MacLeod and D'Amico 2006)
Ginkgo-toothed beaked whale [b] *Mesoplodon gingkodens*	6.00	--	1-10	(Pitman 2002b)	6.00	--	1-10	(Pitman 2002b)
Longman's beaked whale [c] *Indopacetus pacificus*	11.34	11.37	1-100	(MacLeod and D'Amico 2006; Jackson et al. 2008)	11.34	11.37	1-100	(MacLeod and D'Amico 2006; Jackson et al. 2008)
Pygmy beaked whale [a] *Mesoplodon peruvianus*	1.40	0.53	1-2	(Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008)	1.40	0.53	1-2	(Kinzey et al. 2000; Jackson et al. 2004; Jackson et al. 2008)

[a] All Eastern Tropical Pacific data were used due to paucity of data for the Polynesia Region.

[b] General Mesoplodont species data used due to paucity of data for this species.

[c] All Hawaii region data were used due to paucity of data for the Eastern Tropical Pacific and Polynesia Region.

4. GROUP SIZE INFORMATION FOR ODONTOCETES OCCURRING IN THE ATLANTIC OCEAN

4.1 INTRODUCTION

As described in Section 3.1, group size data for Odontocetes are required for use in NAEMO. The purpose of this document is to provide estimates of odontocete group sizes for Phase II analyses in the Atlantic Ocean, covering the previously defined 2nd, 4th, and 6th Fleet AOR excluding the Arctic and Mediterranean Sea (figure 8).

4.2 SPECIES TO MODEL AS GROUPS

As in the Atlantic Ocean, modeling includes marine mammal species that occur from the U.S. coastal waters up to a Foreign Exclusive Economic Zone. Additionally, odontocetes are more likely to occur in large groups at sea than other types of marine mammals and are the only species for which group size data were gathered. Therefore, group size for mysticetes, pinnipeds, and sirenians are not included. Furthermore, because Arctic waters will not be included in the first round of Phase II modeling, Arctic species (i.e., the beluga whale [*Delphinapterus leucas*] and narwhal [*Monodon monoceros*]) were excluded.

4.3 BEST AVAILABLE SCIENCE

A comprehensive and systematic review of relevant literature and data was conducted for completion of this white paper. Of the available published and unpublished literature, the following types of documents were utilized: journals, books, technical reports, cruise reports, raw data from cruises, theses, and dissertations.

Information was collected from the following sources to summarize group size information for all odontocetes that occur in the Atlantic Ocean, excluding FEEZs:

- Marine Biological/Woods Hole Oceanographic Institution Library on-line databases: ScienceDirect, Aquatic Science and Fisheries Abstracts, GeoRef, Biological Sciences, and Web of Science.

- The internet, including various databases and related websites: IUCN, NOAA, NMFS Regional Science Centers, and Google Scholar.

Keywords that were researched included combinations and permutations of the following: common names, genus and species, family names, group, group size, dispersion, dolphin group dispersion, live sighting, cetacean distribution, marine mammal distribution, cruise report, Atlantic Ocean, and beaked whale.

4.4 GROUP SIZE INFORMATION

Data from all relevant sources were pooled based on individual species occurring at the following five locations: Western North Atlantic Ocean, Eastern North Atlantic Ocean, Gulf of Mexico and Caribbean Sea, Western South Atlantic Ocean, and Eastern South Atlantic Ocean with portions of southwestern Indian Ocean (figure 10). Averages of mean group sizes for each species at the five locations were determined, as well as SDs associated with these means. If a range of means was given in any particular study, the maximum value was used to represent the mean. Minimum and maximum group sizes also were determined for each species at each location. In some instances, data were lacking, therefore, data from multiple areas were combined or the geographically closest data were applied. For example, group size data for the Atlantic spotted dolphin (Stenella frontalis) were lacking in the Western South Atlantic Ocean, thus, data from the Eastern South Atlantic were used as surrogates. Moreover, because the range of the Southern right whale dolphin (Lissodelphis peronii) is continuous around South America, data from the Chilean coast were used as surrogates for the Western South Atlantic Ocean (Reeves et al., 2002).

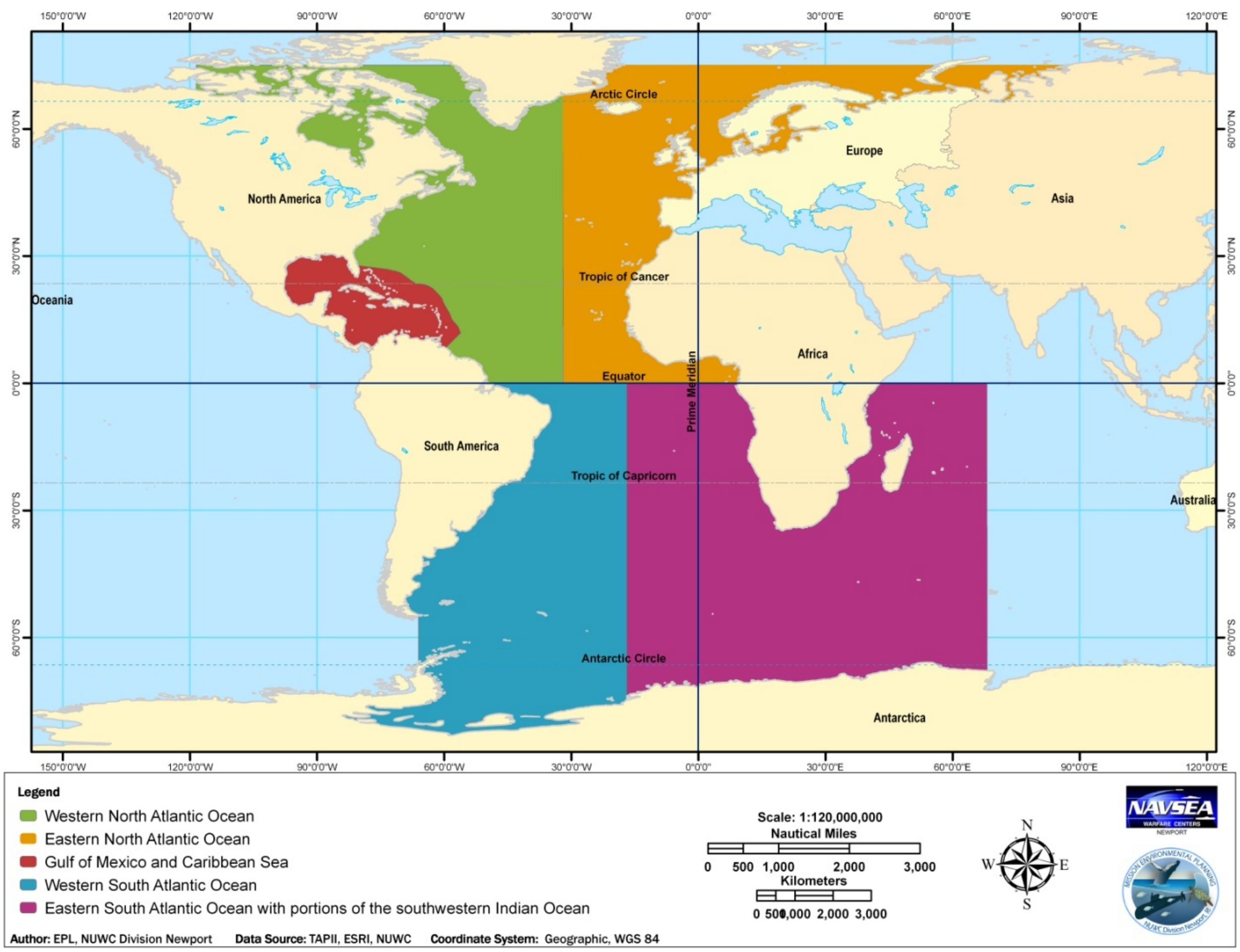

Figure 10. Literature Review Results Delineated Into the Five Locations

The short- and long-beaked common dolphins (*Delphinus delphis* and *D. capensis*, respectively) were only differentiated into two specific species within the last decade. Therefore, data for both species of common dolphin were pooled, and both species are referred to herein as common dolphins (*Delphinus* spp.). Additionally, pygmy and dwarf sperm whales (*Kogia breviceps* and *K. simus*, respectively) often are indistinguishable at sea. Subsequently data for these species were combined, and the species are referred to herein as *Kogia* spp.

Table 121, table 122, and table 123 provide group size information including means, SDs, and ranges for all odontocete species that occur in the Western and Eastern North Atlantic Ocean, the Gulf of Mexico and Caribbean Sea, and the Western and Eastern South Atlantic with portions of the Soutwestern Indian Ocean, respectively.

Table 121. Group Size Information (Means, SDs, and Ranges) for Odontocete Species that Occur in the Western and Eastern North Atlantic Ocean

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Sperm whale *Physeter macrocephalus*	4.47	5.33	1 - 32	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; Hooker 1998; National Marine Fisheries Service (NMFS) 1998a,c,b; Department of the Navy (DoN) 1999; Griffin 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002; Gero et al. 2009)	2.56	2.61	1 - 15	(Øien 1990; Lens 1991; Reiner et al. 1996; Hazevoet and Wenzel 2000; Matthews et al. 2001; Weir et al. 2001; Magalhães et al. 2002; MacLeod et al. 2003b; Moore 2003; Brereton et al. 2004; Kiszka et al. 2007b; de Stephanis et al. 2008; Doksaeter et al. 2008; Waring et al. 2008)
Dwarf and pygmy sperm whales [a] *Kogia* spp.	1.52	0.82	1 - 4	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,c,b,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	1.52	0.82	1 - 4	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,c,b,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Atlantic spotted dolphin *Stenella frontalis*	28.44	10.42	1 - 121	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998b,c,a; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	30.00	--	3 - 50	(Reiner et al. 1996; Moore 2003)
Atlantic white-sided dolphin *Lagenorhynchus acutus*	15.86	17.06	1 - 2500	(Gowans and Whitehead 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Kingsley and Reeves 1998; National Marine Fisheries Service (NMFS) 1998a; Hooker et al. 1999; National Marine Fisheries Service (NMFS) 1999a; Weinrich et al. 2001; Simard et al. 2006)	12.80	4.41	1 - 100	(Weir et al. 2001; MacLeod et al. 2003b; Wall et al. 2006; Doksaeter et al. 2008; Waring et al. 2008)
Bottlenose dolphin *Tursiops truncatus*	14.22	7.59	1 - 350	(Kenney 1990; National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; Gowans and Whitehead 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; Hooker et al. 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002; Beck and Rice 2003)	18.75	15.48	1 - 300	(Reiner et al. 1996; Hazevoet and Wenzel 2000; Weir et al. 2001; Moore 2003; Brereton et al. 2004; Lopez et al. 2004; Wall et al. 2006; Kiszka et al. 2007b; de Stephanis et al. 2008; Bailey and Thompson 2009)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Clymene dolphin [a] *Stenella clymene*	80.00	75.54	2 - 165	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995,1998; National Marine Fisheries Service (NMFS) 1998b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	80.00	75.54	2 - 165	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995,1998; National Marine Fisheries Service (NMFS) 1998b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)
Common dolphins *Delphinus* spp.	27.87	29.13	1 - 700	(Kenney 1990; National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; Gowans and Whitehead 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; Hooker et al. 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	30.87	41.62	1 - 600	(Lens 1991; Reiner et al. 1996; Hazevoet and Wenzel 2000; Weir et al. 2001; MacLeod et al. 2003b; Brereton et al. 2004; Lopez et al. 2004; Wall et al. 2006; Kiszka et al. 2007b; Certain et al. 2008; de Stephanis et al. 2008; Doksaeter et al. 2008; Quérouil et al. 2008; Waring et al. 2008; Freitas et al. 2009)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
False killer whale *Pseudorca crassidens*	5.54	1.71	1 - 23	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	6.25	0.35	6 - 7	(Brereton et al. 2004; Kiszka et al. 2007b)
Fraser's dolphin [b] *Lagenodelphis hosei*	136.63	58.79	7 - 1000	(Findlay et al. 1992; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008; Weir et al. 2008)	136.63	58.79	7 - 1000	(Findlay et al. 1992; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008; Weir et al. 2008)
Killer whale *Orcinus orca*	2.50	0.71	2 - 3	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a,1998a)	7.00	3.92	1 - 30	(Hammond and Lockyer 1988; Øien 1990; Hazevoet and Wenzel 2000; Weir et al. 2001; Nøttestad et al. 2002; Brereton et al. 2004; Foote et al. 2007; Kiszka et al. 2007b; de Stephanis et al. 2008; Doksaeter et al. 2008; Waring et al. 2008)
Long-finned pilot whale *Globicephala melas*	10.21	1.10	1 - 316 [c]	(Anderson and Siegismund 1994; Gowans and Whitehead 1995; Kingsley and Reeves 1998; Hooker et al. 1999; Bloch et al. 2003; de Stephanis et al. 2008)	25.85	30.73	1 - 316	(Brown 1961; Buckland et al. 1993; Anderson and Siegismund 1994; Abend and Smith 1999; Weir et al. 2001; Bloch et al. 2003; MacLeod et al. 2003b; Brereton et al. 2004; Lopez et al. 2004; Wall et al. 2006; Kiszka et al. 2007b; de Stephanis et al. 2008)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Melon-headed whale [d] *Peponocephala electra*	23.26	33.85	2 - 400	(Watkins et al. 1997; Mullin et al. 2004; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)	23.26	33.85	2 - 400	(Watkins et al. 1997; Mullin et al. 2004; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)
Pantropical spotted dolphin [a] *Stenella attenuata*	24.55	23.41	4 - 145	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	24.55	23.41	4 - 145	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)
Pygmy killer whale *Feresa attenuata*	9.17	5.42	3 - 10	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a,1998a; Clarke and Norman 2005)	12.00	0.00 [e]	8 -15	(Williams et al. 2002)
Risso's dolphin *Grampus griseus*	8.47	1.13	1 - 54	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	5.65	3.92	1 - 180	(Reiner et al. 1996; Hazevoet and Wenzel 2000; Weir et al. 2001; Brereton et al. 2004; Wall et al. 2006; Kiszka et al. 2007b; Pereira 2008)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Rough-toothed dolphin *Steno bredanensis*	5.50	3.54	2 - 20	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	13.10	2.69	6 - 20	(Hazevoet and Wenzel 2000; Moore 2003; Ritter 2007)
Short-finned pilot whale *Globicephala macrorhynchus*	15.37	4.78	1 - 135	(Caldwell et al. 1971; National Marine Fisheries Service (NMFS) 1992b; Payne and Heinemann 1993; Department of the Navy (DoN) 1995,1998; National Marine Fisheries Service (NMFS) 1998b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002; Ottensmeyer and Whitehead 2003)	14.24	8.84	1 - 30	(Reiner et al. 1996; Hazevoet and Wenzel 2000; Doksaeter et al. 2008)
Spinner dolphin *Stenella longirostris*	27.60	25.84	1 - 225	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b;	37.67	54.10	3 - 100	(Reiner et al. 1996; Hazevoet and Wenzel 2000)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
				Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)				
Striped dolphin *Stenella coeruleoalba*	45.59	37.50	1 - 400	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; Gowans and Whitehead 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; Griffin 1999; Hooker et al. 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002)	54.46	64.36	1 - 2000	(Lens 1991; Hazevoet and Wenzel 2000; Williams et al. 2002; Brereton et al. 2004; Kiszka et al. 2007b; de Stephanis et al. 2008; Doksaeter et al. 2008; Waring et al. 2008)
White-beaked dolphin *Lagenorhynchus albirostris*	8.72	0.35	2 - 20	(Kingsley and Reeves 1998; Simard et al. 2006; Simard and Gowans 2008)	4.02	1.51	1 - 100	(Øien 1990; Evans et al. 1996; Weir et al. 2001; Hammond et al. 2002; Evans and Hammond 2004; Doksaeter et al. 2008; Waring et al. 2008)
Harbor porpoise *Phocoena phocoena*	2.46	1.30	1 - 25	(National Marine Fisheries Service (NMFS) 1992a,1995a,b,c,d,e,1997b,a; Kingsley and Reeves 1998; National Marine Fisheries Service (NMFS) 1998c,a; Johnston et al. 2005; Simard et al. 2006)	1.70	0.51	1 - 40	(Øien 1990; Weir et al. 2001; Hammond et al. 2002; MacLeod et al. 2003b; Brereton et al. 2004; Siebert et al. 2006; Kiszka et al. 2007b; Bailey and Thompson 2009; Berrow et al. 2009; Gilles et al. 2009)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Blainville's beaked whale [f] *Mesoplodon densirostris*	3.31	1.06	1 - 10	(Ritter and Brederlau 1999; Ritter 2001; Carrillo 2003; Johnson et al. 2004)	3.31	1.06	1 - 10	(Ritter and Brederlau 1999; Ritter 2001; Carrillo 2003; Johnson et al. 2004)
Cuvier's beaked whale *Ziphius cavirostris*	2.77	0.64	1 - 6	(National Marine Fisheries Service (NMFS) 1992b; Department of the Navy (DoN) 1995; National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a; Department of the Navy (DoN) 1998; National Marine Fisheries Service (NMFS) 1998a,b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001,2002; National Marine Fisheries Service (NMFS) 2002; Azzellino et al. 2008)	2.73	0.95	1 - 4	(Ritter 2001; Carrillo 2003; Brereton et al. 2004; Johnson et al. 2004; Kiszka et al. 2007b)
Gervais' beaked whale [f] *Mesoplodon europaeus*	3.00	--	1 - 10	(Pitman 2002b; Carrillo 2003)	3.00	--	1 - 10	(Pitman 2002b; Carrillo 2003)
Northern bottlenose whale *Hyperoodon ampullatus*	3.28	1.68	1 - 14	(National Marine Fisheries Service (NMFS) 1992b; Reeves et al. 1993; Department of the Navy (DoN) 1995,1998; National Marine Fisheries Service (NMFS) 1998b; Department of the Navy (DoN) 1999; National Marine Fisheries Service (NMFS) 1999b; Department of the Navy (DoN) 2000,2001; Gowans et al. 2001; Department of the Navy (DoN) 2002; National Marine Fisheries Service (NMFS) 2002; Whitehead and Wimmer 2005)	2.60	1.12	1 - 10	(Gray 1882; Øien 1990; Bloch et al. 1996; Weir 2000; Weir et al. 2001; Brereton et al. 2004; Kiszka et al. 2007b)

Common and Scientific Names	Western North Atlantic			References	Eastern North Atlantic			References
	mean	SD	range		mean	SD	range	
Sowerby's beaked whale *Mesoplodon bidens*	3.72	1.78	1 - 10	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e,1997a,1998a; Hooker and Baird 1999b)	1.75	1.06	1 - 3	(Weir 2000; Walker et al. 2001; Weir et al. 2001; Pitman 2002b; Kiszka et al. 2007b)
True's beaked whale [g] *Mesoplodon mirus*	1.75	0.96	1 - 3	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e; Tove 1995; National Marine Fisheries Service (NMFS) 1997a,1998a; Brereton et al. 2004; Kiszka et al. 2007b)	1.75	0.96	1 - 3	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e; Tove 1995; National Marine Fisheries Service (NMFS) 1997a,1998a; Brereton et al. 2004; Kiszka et al. 2007b)

[a] All Western North Atlantic data were used due to paucity of data for the Eastern North Atlantic Ocean.

[b] All Eastern South Atlantic and Southwestern Indian data were used due to paucity of data for the Western and Eastern North Atlantic Ocean.

[c] Eastern North Atlantic range was used due to paucity of a range for the Western North Atlantic Ocean.

[d] All Gulf of Mexico and Caribbean Sea data were used due to a paucity of data for the Western and Eastern North Atlantic Ocean.

[e] Zero due to two observations with the same mean.

[f] Eastern North Atlantic mean was used due to paucity of a mean for the Western North Atlantic Ocean.

[g] All available data pooled for summary statistics, irrespective of location.

Table 122. Group Size Information (Means, SDs, and Ranges) for Odontocete Species that Occur in the Gulf of Mexico and Caribbean Sea

Common and Scientific Names	Gulf of Mexico and Caribbean			References
	mean	SD	range	
Sperm whale *Physeter macrocephalus*	3.75	1.74	1 - 30	(Taruski and Winn 1976; Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Roden and Mullin 2000; Weller et al. 2000; Swartz et al. 2001; Mullin et al. 2004; Jérémie et al. 2006; Maze-Foley and Mullin 2006; Richter et al. 2008; Gero et al. 2009)
Dwarf and pygmy sperm whales *Kogia* spp.	2.63	1.18	1 - 12	(Davis and Fargion 1996a,b,c,d; Davis et al. 2000c,a,b; MacLeod et al. 2004; Mullin et al. 2004; Jérémie et al. 2006; Maze-Foley and Mullin 2006; Dunphy-Daly et al. 2008)
Atlantic spotted dolphin *Stenella frontalis*	21.79	22.97	1 - 250	(Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mills and Rademacher 1996; Herzing and Johnson 1997; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Roden and Mullin 2000; Brobeil and Dudzinski 2001; Swartz et al. 2001; Griffin and Griffin 2003; Griffin and Griffin 2004; MacLeod et al. 2004; Mullin et al. 2004; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006; Whaley et al. 2006)
Bottlenose dolphin *Tursiops truncatus*	11.07	10.69	1 - 220	(Taruski and Winn 1976; Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Roden and Mullin 2000; Swartz et al. 2001; Griffin and Griffin 2003; Griffin and Griffin 2004; MacLeod et al. 2004; Mullin et al. 2004; Kerr et al. 2005; Gamboa-Poveda and May-Collado 2006; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006; Whaley et al. 2006)
Clymene dolphin *Stenella clymene*	57.70	34.11	1 - 325	(Davis and Fargion 1996a,b,c,d; Fertl et al. 1997; Davis et al. 2000c,a,b; Jefferson and Curry 2003; Mullin et al. 2004; Maze-Foley and Mullin 2006)
Common dolphins *Delphinus* spp.	6.00	4.53	1 - 50	(Mignucci-Giannoni 1998; Griffin and Griffin 2003)
False killer whale *Pseudorca crassidens*	17.89	8.72	3 - 70	(Davis and Fargion 1996a,b,c,d; Davis et al. 2000c,a,b; Swartz et al. 2001; Mullin et al. 2004; Jérémie et al. 2006; Maze-Foley and Mullin 2006)
Fraser's dolphin *Lagenodelphis hosei*	50.58	28.32	5 - 175	(Jefferson and Leatherwood 1994; Watkins et al. 1994; Mullin et al. 2004; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006)
Killer whale *Orcinus orca*	5.07	3.57	1 - 25	(Mignucci-Giannoni 1998; Bolaños-Jiménez et al. 2006; Maze-Foley and Mullin 2006)
Melon-headed whale *Peponocephala electra*	23.26	33.85	2 - 400	(Watkins et al. 1997; Mullin et al. 2004; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)
Pantropical spotted dolphin *Stenella attenuata*	35.81	29.67	3 - 650	(Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Davis et al. 2000c,a,b; Roden and Mullin 2000; Swartz et al. 2001; Mullin et al. 2004; Bolaños-Jiménez et al. 2006; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006)

Common and Scientific Names	Gulf of Mexico and Caribbean			References
	mean	**SD**	**range**	
Pygmy killer whale *Feresa attenuata*	14.50	4.27	4 - 84	(Davis and Fargion 1996a,b,c,d; Davis et al. 2000c,a,b; Bolaños-Jiménez et al. 2006; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)
Risso's dolphin *Grampus griseus*	13.81	9.30	1 - 40	(Jennings 1982; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; MacLeod et al. 2004; Mullin et al. 2004; Jérémie et al. 2006; Maze-Foley and Mullin 2006)
Rough-toothed dolphin *Steno bredanensis*	12.93	6.16	1 - 57	(Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Swartz et al. 2001; Mullin et al. 2004; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)
Short-finned pilot whale *Globicephala macrorhynchus*	20.83	9.10	1 - 100	(Caldwell and Erdman 1963; Fehring and Wells 1976; Taruski and Winn 1976; Walsh et al. 1991; Mignucci-Giannoni 1998; Roden and Mullin 2000; MacLeod et al. 2004; Mullin et al. 2004; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006)
Spinner dolphin *Stenella longirostris*	130.93	114.09	1 - 800	(Taruski and Winn 1976; Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Swartz et al. 2001; Mullin et al. 2004; Maze-Foley and Mullin 2006)
Striped dolphin *Stenella coeruleoalba*	45.38	39.15	7 - 160	(Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Davis et al. 2000c,a,b; Roden and Mullin 2000; Mullin et al. 2004; Bolaños-Jiménez et al. 2006; Gero and Whitehead 2006; Maze-Foley and Mullin 2006)
Blainville's beaked whale *Mesoplodon densirostris*	3.68	0.42	1 - 11	(MacLeod et al. 2004; Claridge 2006; Claridge and Durban 2008; DiMarzio et al. 2008; Ward et al. 2008)
Cuvier's beaked whale *Ziphius cavirostris*	2.37	0.92	1 - 5	(Jefferson and Lynn 1994; Davis and Fargion 1996a,b,c,d; Mignucci-Giannoni 1998; Davis et al. 2000c,a,b; Swartz et al. 2001; MacLeod et al. 2004; Mullin et al. 2004; Claridge 2006; Gero and Whitehead 2006; Jérémie et al. 2006; Maze-Foley and Mullin 2006; Claridge and Durban 2008)
Gervais' beaked whale *Mesoplodon europaeus*	3.00	0.00 [a]	2 - 4	(Claridge and Durban 2008; Gillespie et al. 2009)

[a] Zero due to two observations with the same mean.

Table 123. Group Size Information (Means, SDs, and Ranges) for Odontocete Species that Occur in the Western and Eastern South Atlantic Ocean with Portions of the Southwestern Indian Ocean

Common and Scientific Names	Western South Atlantic			References	Eastern South Atlantic and Indian			References
	mean	SD	range		mean	SD	range	
Sperm whale *Physeter macrocephalus*	2.47	1.76	1 - 65 [a]	(Kasamatsu and Joyce 1995; Martuscelli et al. 1996; Pinedo et al. 2002)	7.94	6.04	1 - 65	(Kasamatsu and Joyce 1995; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Best et al. 2009)
Dwarf and pygmy sperm whales [b] *Kogia* spp.	1.38	0.32	1 - 6	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)	1.38	0.32	1 - 6	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)
Atlantic spotted dolphin [b] *Stenella frontalis*	103.90	125.1	1 - 500	(Weir 2007)	103.90	125.1	1 - 500	(Weir 2007)
Bottlenose dolphin *Tursiops truncatus*	15.00	3.28	2 - 22	(Würsig and Würsig 1977; Martuscelli et al. 1996)	33.93	40.09	1 - 120	(Ballance et al. 2001; Kiszka et al. 2007a; Weir 2007)
Clymene dolphin *Stenella clymene*	76.10	11.00	1 - 1000	(Fertl et al. 2003)	76.10	11.00	1 - 1000	(Fertl et al. 2003)
Common dolphins *Delphinus* spp.	27.00	14.12	6 - 30	(Martuscelli et al. 1996; Pinedo et al. 2002)	166.50	91.54	1 - 1000	(Findlay et al. 1992; Ballance and Pitman 1998; Weir 2007; Best et al. 2009)
Dusky dolphin *Lagenorhynchus obscurus*	32.50	24.75	1 - 300	(Würsig and Würsig 1980; Coscarella et al. 2003)	36.16	1.79	2 - 800	(Cruickshank and Brown 1981; Findlay et al. 1992)
False killer whale [b] *Pseudorca crassidens*	65.81	62.74	1 - 835	(Ross 1984; Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)	65.81	62.74	1 - 835	(Ross 1984; Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)
Fraser's dolphin [b] *Lagenodelphis hosei*	136.63	58.79	7 - 1000	(Findlay et al. 1992; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008; Weir et al. 2008)	136.63	58.79	7 - 1000	(Findlay et al. 1992; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008; Weir et al. 2008)

Common and Scientific Names	Western South Atlantic			References	Eastern South Atlantic and Indian			References
	mean	SD	range		mean	SD	range	
Hourglass dolphin *Lagenorhynchus cruciger*	5.72	0.98	1 - 16	(Kasamatsu and Joyce 1995; Goodall 1997; Thiele et al. 2004)	7.64	1.32	1 - 100	(Kasamatsu et al. 1988; Kasamatsu and Joyce 1995)
Killer whale *Orcinus orca*	5.96	4.19	2 - 5	(Kasamatsu and Joyce 1995; Martuscelli et al. 1996; Pinedo et al. 2002)	5.71	1.82	1 - 12	(Findlay et al. 1992; Kasamatsu and Joyce 1995; Ballance and Pitman 1998; Anderson 2005; Weir 2007; Best et al. 2009; Williams et al. 2009)
Long-finned pilot whale [c] *Globicephala melas*	68.88	5.69	1 - 249	(Kasamatsu et al. 1988; Kasamatsu and Joyce 1995)	68.88	5.69	1 - 249	(Kasamatsu et al. 1988; Kasamatsu and Joyce 1995)
Melon-headed whale [b] *Peponocephala electra*	339.86	104.1	30 - 1200	(Ballance and Pitman 1998; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)	339.86	104.1	30 - 1200	(Ballance and Pitman 1998; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)
Pantropical spotted dolphin [b] *Stenella attenuata*	88.98	32.10	3 - 300	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)	88.98	32.10	3 - 300	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)
Pygmy killer whale [b] *Feresa attenuata*	13.96	6.91	9 - 30	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a)	13.96	6.91	9 - 30	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a)
Risso's dolphin [b] *Grampus griseus*	21.33	16.00	1 - 300	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)	21.33	16.00	1 - 300	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007)
Rough-toothed dolphin [b] *Steno bredanensis*	22.78	5.24	6 - 40	(Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)	22.78	5.24	6 - 40	(Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)
Short-finned pilot whale [b] *Globicephala macrorhynchus*	35.88	19.81	3 - 200	(Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)	35.88	19.81	3 - 200	(Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Weir 2007; Dulau-Drouot et al. 2008)

Common and Scientific Names	Western South Atlantic			References	Eastern South Atlantic and Indian			References
	mean	SD	range		mean	SD	range	
Southern right whale dolphin *Lissodelphis peronii*	194.85	168.8	1 - 1200	(Kasamatsu et al. 1988; Waerebeek et al. 1991; Jefferson et al. 1994)	101.81	71.12	2 - 300	(Cruickshank and Brown 1981; Brown 1982; Rose and Payne 1991; Findlay et al. 1992; Ballance and Pitman 1998)
Spinner dolphin [b] *Stenella longirostris*	80.00	50.85	3 - 750	(Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008)	80.00	50.85	3 - 750	(Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a; Dulau-Drouot et al. 2008)
Striped dolphin [b] *Stenella coeruleoalba*	52.74	14.32	3 - 200	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)	52.74	14.32	3 - 200	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)
Andrew's beaked whale *Mesoplodon bowdoini*	6.00	--	1 - 10	(Pitman 2002b)	6.00	--	1 - 10	(Pitman 2002b)
Arnoux's beaked whale [d] *Berardius arnuxii*	2.75	2.22	1 - 80	(Kasamatsu et al. 1988; Balcomb 1989)	2.75	2.22	1 - 80	(Kasamatsu et al. 1988; Balcomb 1989)
Blainville's beaked whale [b] *Mesoplodon densirostris*	2.57	1.10	1 - 6	(Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a)	2.57	1.10	1 - 6	(Ballance et al. 2001; Anderson 2005; Kiszka et al. 2007a)
Cuvier's beaked whale [b] *Ziphius cavirostris*	2.16	0.90	1 - 4	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)	2.16	0.90	1 - 4	(Findlay et al. 1992; Ballance and Pitman 1998; Ballance et al. 2001; Anderson 2005; Weir 2007)
Gervais' beaked whale [e] *Mesoplodon europaeus*	N/A [f]	N/A	N/A	N/A	3.00	--	1 - 10	(Pitman 2002b; Carrillo 2003)
Gray's beaked whale *Mesoplodon grayi*	6.00	--	1 - 10	(Pitman 2002b; Reeves et al. 2002)	6.00	--	1 - 10	(Pitman 2002b; Reeves et al. 2002)
Hector's beaked whale *Mesoplodon hectori*	6.00	--	1 - 10	(Pitman 2002b)	6.00	--	1 - 10	(Pitman 2002b)
Longman's beaked whale *Indopacetus pacificus*	N/A	N/A	N/A	N/A	3.75	3.89	1 - 20	(Anderson 2005; Kiszka et al. 2007a)
Shepherd's beaked whale [b] *Tasmacetus shepherdi*	5.00	1.41	4 - 6	(Pitman et al. 2006; Best et al. 2009)	5.00	1.41	4 - 6	(Pitman et al. 2006; Best et al. 2009)

Common and Scientific Names	Western South Atlantic			References	Eastern South Atlantic and Indian			References
	mean	SD	range		mean	SD	range	
Southern bottlenose whale *Hyperoodon planifrons*	2.24	1.39	1 - 8	(Kasamatsu et al. 1988)	4.62	2.74	1 - 15	(Findlay et al. 1992; Gowans 2002)
Strap-toothed whale [b] *Mesoplodon layardii*	4.67	1.15	4 - 6	(Findlay et al. 1992)	4.67	1.15	4 - 6	(Findlay et al. 1992)
True's beaked whale [d] *Mesoplodon mirus*	N/A	N/A	N/A	N/A	1.75	0.96	1 - 3	(National Marine Fisheries Service (NMFS) 1995a,b,c,d,e; Tove 1995; National Marine Fisheries Service (NMFS) 1997a,1998a; Brereton et al. 2004; Kiszka et al. 2007b)

[a] Eastern South Atlantic and southwestern Indian range was used due to a paucity of a range for the Western South Atlantic Ocean.

[b] All Eastern South Atlantic and Southwestern Indian data were due to paucity of data for the Western South Atlantic Ocean.

[c] All Western South Atlantic data were used due to paucity of data for the Eastern South Atlantic and Southwestern Indian Oceans.

[d] All available data pooled for summary statistics, irrespective of location

[e] All Eastern North Atlantic data were used due to paucity of data for the Eastern South Atlantic and Southwestern Indian Oceans.

[f] N/A denotes species is not known to occur at this location

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