AMENDED NMFS INCIDENTAL HARASSMENT AUTHORIZATION APPLICATION

SPECTRUM GEO INC.
ATLANTIC 2D GEOPHYSICAL SURVEY

18 September 2015

Related Environmental Document

Atlantic OCS Proposed Geological and Geophysical Activities Mid-Atlantic and South Atlantic Planning Areas Final Programmatic Environmental Impact Statement (OCS EIS/EA BOEM 2014-001)

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NMFS INCIDENTAL HARASSMENT AUTHORIZATION APPLICATION SPECTRUM GEO INC. ATLANTIC 2D GEOPHYSICAL SURVEY

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05	9/18/15	Remove Detailed Grid	K. Olsen	J. Young, MJ. Barkaszi	K. Olsen

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2D	two-dimensional
BOEM	Bureau of Ocean Energy Management
BSEE	Bureau of Safety and Environmental Enforcement
CETAP	Cetacean and Turtle Assessment Program
dB	decibels
DMA	Dynamic Management Area
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
ESA	Endangered Species Act
HESS	High Energy Seismic Survey Team
HMS	Highly Migratory Species
Hz	hertz (cycles per second)
IHA	Incidental Harassment Authorization
IUCN	International Union for the Conservation of Nature
IWCI	International Whaling Commission
kHz	kilohertz
kn	knots (nautical miles per hour)
MAB	Mid-Atlantic Bight
MMPA	Marine Mammal Protection Act
MPa	megapascal
NARWSS	North Atlantic Right Whale Sighting Survey
NMFS	National Marine Fisheries Service
nmi	nautical mile
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanic and Atmospheric Administration
NTL	Notice to Lessees
OCS	Outer Continental Shelf
Pa	pascal
PAM	Passive Acoustic Modeling
PEIS	Programmatic Environmental Impact Statement
PSO	Protected Species Officer
PTS	Permanent Threshold Shift
rms	root mean square
SDSS	Spatial Decision Support System
SEL	Sound Exposure Level
SERDP	Strategic Environmental Research and Development
SMA	Seasonal Management Area
Spectrum	Spectrum Geo Inc.
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
µPa	micropascal
UME	Unusual Mortality Event
USDOC	U.S. Department of Commerce
USDON	U.S. Department of the Navy

1.0 DESCRIPTION OF THE ACTIVITIES

A detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals.

1.1 GENERAL DESCRIPTION OF ACTIVITIES

This section addresses the National Marine Fisheries Service (NMFS) Incidental Harassment Authorization (IHA) requirement to provide a detailed description of the specific activity or class of activities that can be expected to result in incidental taking of marine mammals. Spectrum Geo Inc. (Spectrum) will use one survey vessel to conduct a two-dimensional (2D) geophysical survey offshore portions of the U.S. Atlantic coast within the Mid- and South Atlantic Planning Areas from Delaware to northern Florida (**Figure 1**). This description of activities is based on the expectation that seismic survey activities will occur in the project area for a period of 5-6 months. Seismic survey activities will be conducted 24 hours per day, 7 days per week in a manner consistent with industry best practices. This amended application removes the request to perform the previously identified Detailed Grid portion of the survey and only request performance of the Regional survey gridlines, henceforth referred to as the survey grid.

The survey design consists of a grid that extends throughout the Mid- and South Atlantic Planning Areas and will be conducted in an approximately 25 × 32 km (13.5 × 17.3 nautical mile [nmi]) grid. **Figure 1** shows the variable grid sizes to minimize the overall survey distances. Within the survey grid, streamers will be 12 km (6.5 nmi) in length.

The source vessel will deploy an array of 32 airguns as an energy source at a tow depth of 6 to 10 m (20 to 33 ft) below the sea surface. The source array comprises 4 subarrays, each with 8 – 10 individual airguns. Each subarray is separated by approximately 10 m (33 ft). The receiving system will be towed at 10 to 20 m (33 to 66 ft) depth. As the airgun array is towed along the survey lines, hydrophones along the streamers will receive the returning acoustic signals and transfer the data to the shipboard processing system.

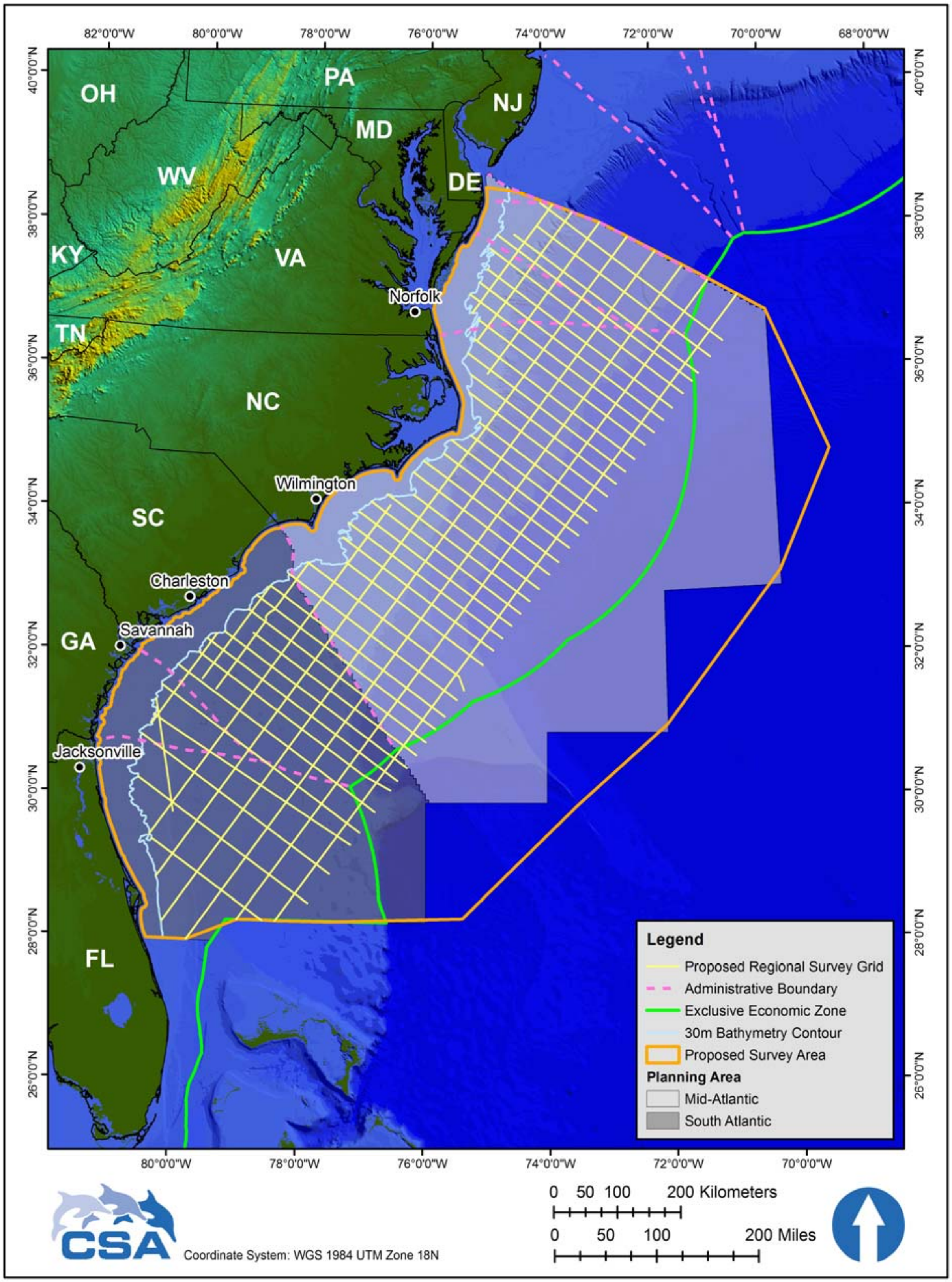

Figure 1. Project area in which 2D seismic survey activities for the survey grid is proposed.

1.2 VESSEL SPECIFICATIONS

The survey source vessel and associated chase or support vessels (one) has not yet been determined for the proposed survey. A schematic showing an example survey vessel and planned 2D seismic array is provided in **Figure 2**.

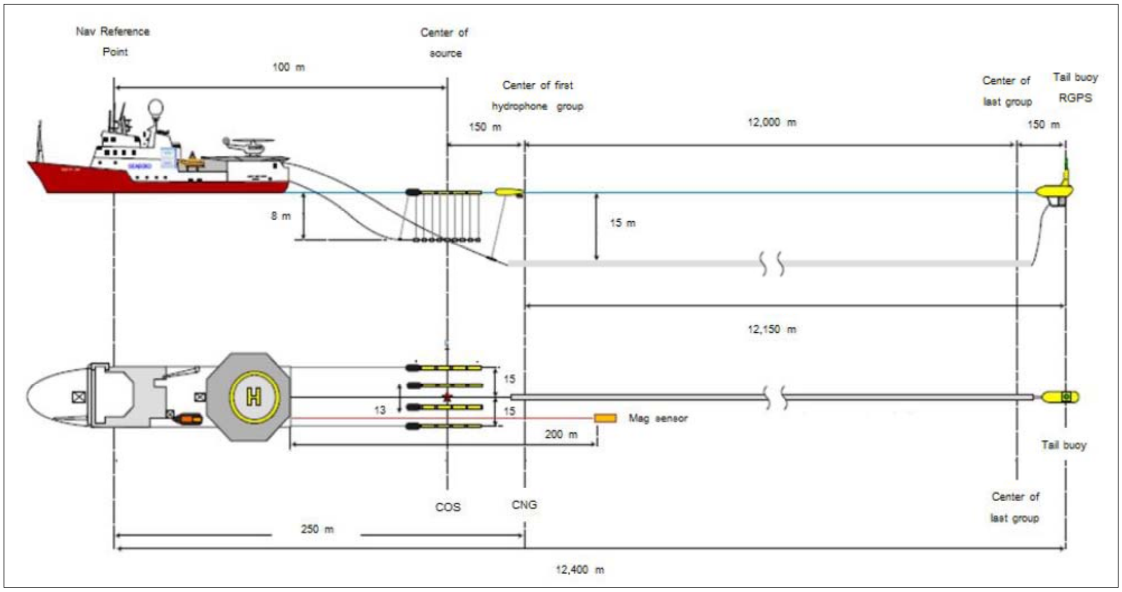

Figure 2. Schematic of an example survey vessel and 2D seismic array.

1.3 DESCRIPTION OF PROPOSED 2D SEISMIC SURVEYS

The only type of acoustic equipment other than navigational equipment (i.e., depth sounder) intended for use during the 2D seismic surveys is an airgun array. A magnetometer will also be used, but because it is a non-acoustic instrument used to measure the strength and, in some cases, the direction of magnetic fields, it will not be discussed further in this IHA Application. An airgun array summary is provided in **Table 1**.

Table 1. Airgun array summary for the proposed survey for the source vessel.

Array Parameter: (0 to 50,000) Hz	Array Value
Number of guns	32
Total volume (in3)	4,920.0 (80.6 L)
Peak-to-peak in bar-m	394 +/- 3.5 (39.4 +/- 0.35 MPa, ~272 dB re 1 µPa @ 1 m)
Zero-to-peak in bar-m	189 (18.9 MPa, 266 dB re 1 µPa @ 1 m)
RMS pressure in bar-m	14.6 (1.46 MPa, 243 dB re 1 µPa @ 1 m)
Primary to bubble (peak to peak)	25.9 +/- 9.4
Bubble period to first peak (s)	0.103 +/- 0.0303
Maximum spectral ripple (dB): 10.0 to 50.0 Hz	8.15
Maximum spectral value (dB): 10.0 to 50.0 Hz	219
Average spectral value (dB): 10.0 to 50.0 Hz	216
Total acoustic energy (Joules)	551,443.5
Total acoustic efficiency (%)	49.6

The survey will comprise approximately 21,534 km (11,619 nmi) line distance of 2D seismic surveying including turns, not including transits to and from the survey area when airguns will not be in use. There will be additional seismic operations in the survey area associated with airgun testing and repeat coverage of any areas where initial data quality is substandard. As a contingency, it is expected that an additional 100 km (54 nmi) may need to be re-surveyed due to lines being suspended for environmental reasons (e.g. protected species inside the exclusion zone) and technical reasons (e.g. recording equipment or source array outside of operational specifications) for a total of 21,635 km (11,682 nmi).

While the survey vessel is recording seismic reflection data, the survey arigun array will fire exclusively on a fixed distance interval or shot point (SP) interval of 25 m (approximately 82 ft), reflecting a time interval of approximately 10 seconds.

2.0 DATES, DURATION, AND LOCATION OF THE ACTIVITIES

The date(s) and duration of such activity and the specific geographical region where it will occur.

2.1 SURVEY DATES AND DURATION

The survey activities are anticipated to commence in February 2016. The 6-month program will consist of 165 days of seismic operations. The actual dates of proposed activities depend on logistics, weather conditions, and the need to repeat some lines if data quality is substandard. The anticipated completion date is July 2016.

2.2 SPECIFIC GEOGRAPHIC REGION

The proposed survey for the survey will encompass offshore of portions of the U.S. Atlantic coast within the Mid- and South Atlantic Planning Areas from Delaware to northern Florida as shown in **Figure 1**. Water depths in the survey grid range from approximately 30 to 5,410 m (98 to 17,749 ft). There will be no survey activity data collection performed in state waters with only survey tie-in lines that are perpendicular to the shore that approach the state-federal line and the eastern most survey lines extending out to the extended continental shelf boundary, located 350 nm from shore. The closest parallel line to shore is located approximately 35.7 km (19.3 nmi) from Hatteras Beach North Carolina's Eastern Shore and the furthest planned survey line located approximately 280 km (175 miles) offshore Hatteras Beach, North Carolina.

3.0 Marine Mammal Species and Abundance in the Proposed Survey Area

The species and numbers of marine mammals likely to be found within the activity area.

In the western North Atlantic Ocean, including the area of the proposed survey, there are 39 species of marine mammals belonging to three taxonomic orders: Cetacea, Sirenia, and Carnivora (Waring et al., 2014). Cetacea includes all whales, dolphins, and porpoises, and it is further subdivided into two suborders: Mysticeti (baleen whales) and Odontoceti (toothed whales, dolphins, and porpoises). Sirenia includes all sea cows, including manatees. Marine mammals of the order Carnivora that may occur within the proposed survey area include members of the suborder Pinnipedia (true seals) (Jefferson et al., 2008). Cetaceans and pinnipeds are the subject of this IHA application to NMFS.

To avoid redundancy, the required information about marine mammal species that are known to or may be present within the proposed survey area and available information on population estimates of these species are provided in **Section 4.0**.

4.0 AFFECTED SPECIES STATUS AND DISTRIBUTION

A description of the status, distribution, and seasonal distribution (when applicable) of the affected species or stocks of marine mammals likely to be affected by such activities.

Sections 3.0 and **4.0** are integrated here to minimize repetition. A listing of marine mammal species that may occur within the proposed survey area, including current status, occurrence, and habitat is provided in **Table 2**. All marine mammal species within U.S. waters are protected under the Marine Mammal Protection Act (MMPA) of 1972. Some species are further protected under the Endangered Species Act (ESA) of 1973. Under the ESA, a species is considered *endangered* if it is "in danger of extinction throughout all or a significant portion of its range." A species is considered *threatened* if it "is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

The MMPA prohibits, with certain exceptions, the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S. *Take* is defined under the MMPA as "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (16 U.S.C. 1362). Some marine mammal species or specific stocks (defined as a group of nonspecific individuals that are managed separately [Wang, 2002]) may be designated as *strategic* under the MMPA, which requires the jurisdictional agency (NMFS or FWS) to impose additional protection measures. A stock is considered strategic if:

- direct human-caused mortality exceeds its Potential Biological Removal (PBR) level (defined as the maximum number of animals, not including natural mortality, that can be removed from the stock while allowing the stock to reach or maintain its optimum sustainable population level);
- it is listed under the ESA;
- it is declining and likely to be listed under the ESA; or
- it is designated as depleted under the MMPA.

A *depleted* species or population stock is defined by the MMPA as any case in which:

- the Secretary, after consultation with the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals established under MMPA title II, determines that a species or population stock is below its optimum sustainable population;
- a State, to which authority for the conservation and management of a species or population stock is transferred under section 109, determines that such species or stock is below its optimum sustainable population; or
- a species or population stock is listed as an endangered species or a threatened species under the ESA.

Seven marine mammal species that occur in the western North Atlantic Ocean are federally listed as endangered under the ESA (USDOC, NMFS, 2014). These include five mysticete (i.e., baleen) whales (North Atlantic right whale, blue whale, fin whale, sei whale, and humpback whale), one odontocete (i.e., toothed) whale (sperm whale), and one sirenian (West Indian manatee) (Waring et al., 2014; USDOC, NMFS, 2014) (**Table 2**). The remaining 32 nonlisted species known to occur within the western North Atlantic Ocean include 2 mysticete whales, 26 odontocete whales and dolphins, and 4 pinnipeds (seals).

Of the mysticete whales listed in **Table 2**, the fin whale, North Atlantic right whale, and humpback whale may occur regularly within the proposed survey area (Waring et al., 2014). The remaining four species (minke whale, sei whale, Bryde's whale, and blue whale) are considered rare or extralimital in the western North Atlantic Ocean, including the proposed survey area (Waring et al., 2014). However, recent acoustic data (Norris et al., 2013, Risch et al., 2013) suggest that minke whales may occur within the south Atlantic Bight year-round, with increased densities during the winter months. Annual Stock Assessment Reports generated by NMFS that provide information on the geographic range and/or habitat preference of the 27 odontocete whale and dolphin species listed in **Table 2** suggest that all may occur within the proposed survey area (Waring et al., 2014, 2013, 2011, 2008, 2001). Sixteen species may occur regularly within the proposed survey area, and 10 species are considered rare. One species (false killer whale) lacks sufficient data to determine its presence within the survey area.

The West Indian manatee occurs primarily in coastal and occasionally nearshore waters of the continental shelf, and thus would not be expected to occur in the proposed survey area (Waring et al., 1995). Manatees are under the jurisdiction of the U.S. Fish and Wildlife Service and will not be discussed further in this IHA Application to NMFS.

Four species of seals are known to occur in the western North Atlantic (Jefferson et al., 2008). The normal range of harp and hooded seals is north of the proposed survey area and are thus considered rare in this area. Gray seals and harbor seals may occur within the survey area but probably only within waters of the continental shelf (Waring et al., 2014).

A summary of information on the status and distribution of each marine mammal species (or species group) is provided in **Section 4.1** for listed species and in **Section 4.2** for nonlisted species.

Table 2. Marine mammals that may potentially occur in the proposed survey area.

Common Name	Species	MMPA Stock(s)[1]	ESA/ Stock Status[2]	Occurrence in Proposed Survey Area[3]	Best Pop. Estimate[4]	Habitat[5]	Season(s) within Proposed Survey Area[3]
ORDER CARNIVORA							
Suborder Pinnipedia (Sea Lions and Eared Seals, Walrus, and True Seals)							
Harp Seal	*Phoca groenlandica*	Western North Atlantic		Rare	N/A[7]	C, IS	Fall to Spring
Harbor Seal	*Phoca vitulina*	Western North Atlantic		Rare	N/A[7]	C, IS	Fall to Spring
Gray Seal	*Halichoerus grypus*	Western North Atlantic		Rare	N/A[7]	C, IS	Fall to Spring
Hooded Seal	*Cystophora cristata*	Western North Atlantic		Rare	70,142	C, IS	Fall to Spring
ORDER CETACEA							
Suborder Mysticeti (Baleen Whales)							
North Atlantic Right Whale	*Eubalaena glacialis*	Western Atlantic	E/S,D	Regular	455	IS, OS	Fall to Spring
Humpback Whale	*Megaptera novaeangliae*	Gulf of Maine	E/S,D	Regular	823	IS, OS	Fall to Spring
Common Minke Whale	*Balaenoptera a. acutorostrata*	Canadian East Coast		Rare	16,199	IS, OS	All Seasons
Sei Whale	*Balaenoptera borealis*	Nova Scotia	E/S,D	Rare	236	OS, O	N/A
Bryde's Whale	*Balaenoptera brydei*	N/A		Rare	N/A	IS, OS	N/A
Blue Whale	*Balaenoptera musculus*	Western North Atlantic	E/S,D	Rare	N/A	OS, O	N/A
Fin Whale	*Balaenoptera physalus*	Western North Atlantic	E/S,D	Regular	3,522	IS, OS, O	All Seasons
Suborder Odontoceti (Toothed Whales, Dolphins, and Porpoises)							
Sperm Whale	*Physeter macrocephalus*	North Atlantic	E/S,D	Regular	2,288	OS, O	N/A
Pygmy Sperm Whale	*Kogia breviceps*	Western North Atlantic		Regular	3,785	OS, O	N/A
Dwarf Sperm Whale	*Kogia sima*	Western North Atlantic		Regular		OS, O	N/A
Cuvier's Beaked Whale	*Ziphius cavirostris*	Western North Atlantic		Regular	6,532	OS, O	N/A
Northern Bottlenose Whale	*Hyperoodon ampullatus*	Western North Atlantic		Rare	N/A	OS, O	N/A
Sowerby's Beaked Whale	*Mesoplodon bidens*	Western North Atlantic		Regular	7,092	OS, O	N/A
Blainville's Beaked Whale	*Mesoplodon densirostris*	Western North Atlantic		Regular		OS	N/A

Common Name	Species	MMPA Stock(s)[1]	ESA/ Stock Status[2]	Occurrence in Proposed Survey Area[3]	Best Pop. Estimate[4]	Habitat[5]	Season(s) within Proposed Survey Area[3]
Gervais' Beaked Whale	*Mesoplodon europaeus*	Western North Atlantic		Regular		OS, O	N/A
True's Beaked Whale	*Mesoplodon mirus*	Western North Atlantic		Regular		OS, O	N/A
Rough-Toothed Dolphin	*Steno bredanensis*	Western North Atlantic		Rare	271	OS, O	N/A
Bottlenose Dolphin[6]	*Tursiops truncatus*	Western North Atlantic Offshore		Regular	77,532	OS	All Seasons
		Western North Atlantic Northern Migratory Coastal	S,D	Regular	11,548	C, IS	All Seasons
		Western North Atlantic Southern Migratory Coastal Stock	S,D	Regular	9,173	C	All Seasons
		Western North Atlantic South Carolina/Georgia Coastal Stock	S,D	Regular	74,377	C	All Seasons
		Western North Atlantic Northern Florida Coastal Stock	S,D	Regular	1,219	C	All Seasons
		Western North Atlantic Central Florida Coastal Stock	S,D	Regular	4,895	C	All Seasons
Pantropical Spotted Dolphin	*Stenella attenuata*	Western North Atlantic		Regular	3,333	OS, O	N/A
Clymene Dolphin	*Stenella clymene*	Western North Atlantic		Rare	N/A	O	N/A
Striped Dolphin	*Stenella coeruleoalba*	North Atlantic		Regular	54,807	OS, O	All Seasons
Atlantic Spotted Dolphin	*Stenella frontalis*	Western North Atlantic		Regular	44,715	OS	All Seasons
Spinner Dolphin	*Stenella longirostris*	Western North Atlantic		Rare	N/A	IS, OS, O	N/A
Short-beaked Common Dolphin	*Delphinus delphis*	Western North Atlantic		Regular	173,486	OS,O	Fall to Spring
Atlantic White-sided Dolphin	*Lagenodelphis acutus*	Western North Atlantic		Rare	48,819	OS, O	N/A
White-beaked Dolphin	*Lagenodelphis albirostris*	Western North Atlantic		Rare	2,003	IS, OS	N/A
Fraser's Dolphin	*Lagenodelphis hosei*	North Atlantic		Rare	N/A	IS, OS, O	N/A
Risso's Dolphin	*Grampus griseus*	Western North Atlantic		Regular	18,250	OS, O	N/A

Common Name	Species	MMPA Stock(s)[1]	ESA/ Stock Status[2]	Occurrence in Proposed Survey Area[3]	Best Pop. Estimate[4]	Habitat[5]	Season(s) within Proposed Survey Area[3]
Melon-Headed Whale	*Peponocephala electra*	Western North Atlantic		Rare	N/A	O	N/A
Pygmy Killer Whale	*Feresa attenuata*	Western North Atlantic		Rare	N/A	O	N/A
False Killer Whale	*Pseudorca crassidens*	N/A		N/A	N/A	IS, OS, O	N/A
Killer Whale	*Orcinus orca*	Western North Atlantic		Rare	N/A	IS, OS, O	N/A
Short-Finned Pilot Whale	*Globicephala macrorhynchus*	Western North Atlantic		Regular	21,515	OS, O	All Seasons
Long-Finned Pilot Whale	*Globicephala melas*	Western North Atlantic		Regular	26,535	OS, O	Winter to Spring
Harbor Porpoise	*Phocoena phocoena*	Gulf of Maine/ Bay of Fundy		Rare	79,883	C, IS	N/A

N/A = Not available.

1 MMPA = Marine Mammal Protection Act; Stock = defined as a group of nonspecific individuals that are managed separately.

2 ESA = Endangered Species Act; E = endangered; S = MMPA "strategic" stock; D = MMPA "depleted' stock.

3 Occurrence and Season(s) in Proposed Survey Area from NMFS Stock Assessment Reports (Waring et al., 2014, 2013, 2011, 2008, 2001).

4 Best population estimate "NBest" from Table 1 of the Waring et al. (2014) stock assessment report except for Bryde's whale (Waring et al., 2012) . "NBest" is combined for 2 *Kogia* species and 4 *Mesoplodon* species due to difficulties in differentiating these species in the field.

5 C = coastal (embayments and inshore waters, and nearshore waters); IS = inner continental shelf; OS = outer continental shelf and shelf edge; O= oceanic (continental slope and beyond) (from NMFS Stock Assessment Reports (Waring et al., 2014, 2013, 2011, 2008, 2001) and Jefferson et al., 2008).

6 Additional coastal stocks of bottlenose dolphins that inhabit inshore waters of bays, sounds and estuaries along the eastern U.S. are currently recognized but their range is outside of the proposed survey area. These stocks are discussed in Section 4.2.

7 Abundance estimates are not available for the U.S populations of these species.

4.1 LISTED MARINE MAMMALS

North Atlantic Right Whale (*Eubalaena glacialis*)

The North Atlantic right whale is the only member of the mysticete family Balaenidae found in North Atlantic waters. It is medium in size when compared to other mysticete species, with adult sizes ranging from 14 to 17 m (46 to 56 ft) (USDOC, NMFS, 2005).

Status

The North Atlantic right whale is considered one of the most critically endangered whales (Jefferson et al., 2008). It is listed as endangered under the ESA, and the western Atlantic stock is classified under the MMPA as strategic and depleted (Waring et al., 2014). Today, the minimum population size of the Western Atlantic North Atlantic right whale is approximately 455 individuals (Waring et al., 2014). Continued threats to this species include commercial fishing interactions, vessel strikes, acoustic habitat masking by underwater noise, habitat degradation, and predators (USDOC, NMFS, 2005; Waring et al., 2014).

In 1994, three critical habitats for the North Atlantic right whale were designated by NMFS along the eastern coast of the U.S. (*Federal Register* 59 FR 28805, 1994) (**Figure 3)**. These include the following:

- Cape Cod Bay/Massachusetts Bay;
- Great South Channel; and
- Selected areas off the southeastern U.S.

In 2009, NMFS received a petition to expand the critical habitat, and the agency is continuing its ongoing rulemaking process. NMFS initially had the expectation that a proposed critical habitat rule would be submitted for publication in the *Federal Register* in the second half of 2011 (*Federal Register* 75 FR 61690, 2010); as of November 2014, expansion of the North Atlantic right whale critical habitat remains under review.

Seasonal Management Areas (SMAs) for reducing ship strikes of the North Atlantic right whale have also been designated in the U.S. and Canada (**Figure 3**). All vessels greater than 19.8 m (65 ft) in overall length must operate at speeds of 10 knots (kn) or less within these areas during specified time periods. Details for SMAs are presented in **Table 3**.

Table 3. Designated U.S. Seasonal Management Areas (SMAs) for the North Atlantic right whale within the proposed survey area.

Regional Area	Individual Areas	Concerns	Period of Activity
Mid-Atlantic U.S. SMAs	Entrance to Delaware Bay	Migratory Route and Calving Grounds	1 November to 30 April
	Entrance to Chesapeake Bay		
	Ports of Morehead City and Beaufort, NC		
	Wilmington, NC to Brunswick, GA		
Southeast U.S. SMA	Central Georgia to northeast Florida	Calving and Nursery Grounds	15 November to 15 April

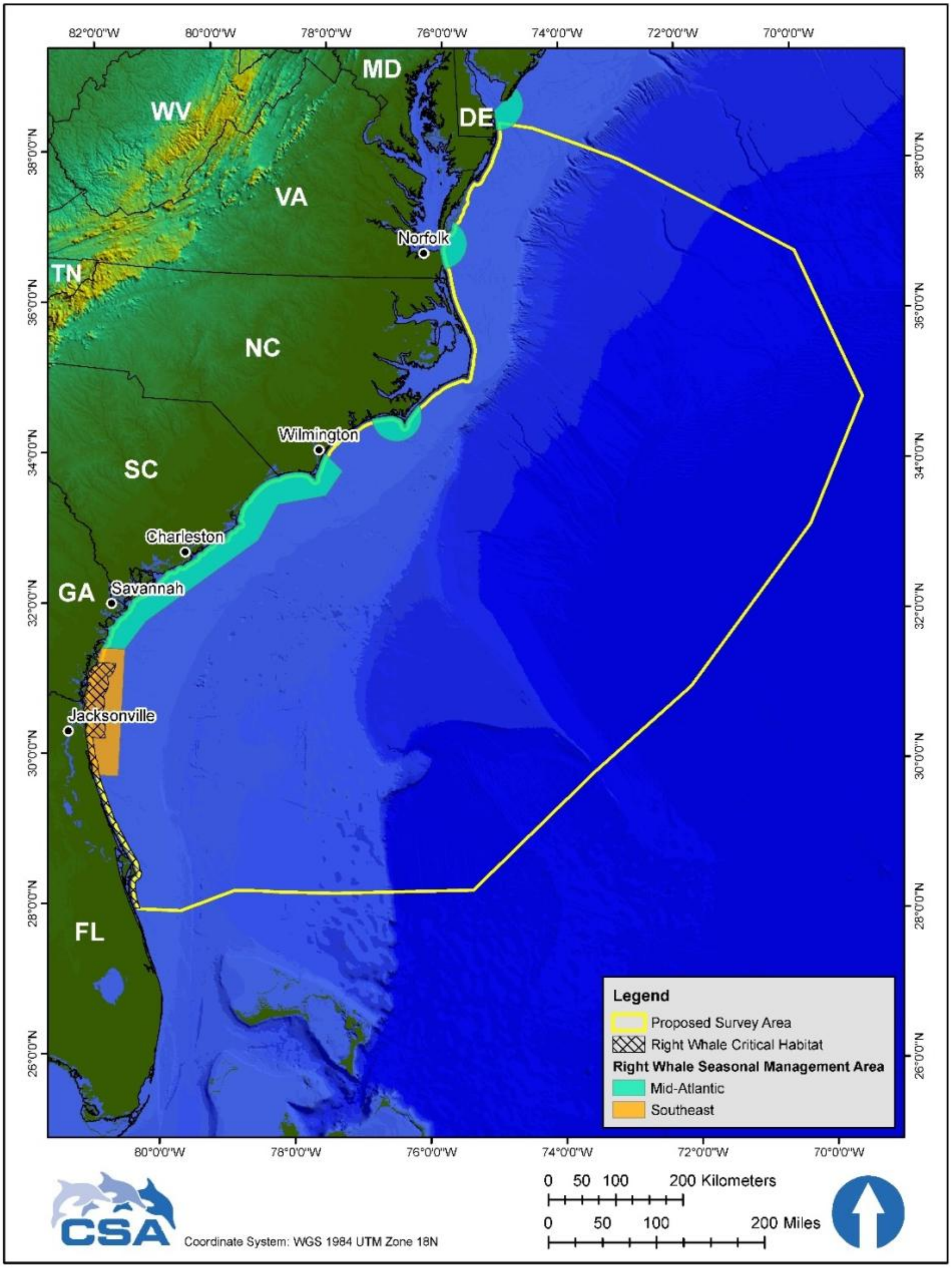

Figure 3. North Atlantic right whale critical habitat and U.S. Seasonal Management Areas (50 CFR § 224.105) within the proposed survey area.

Distribution

The North Atlantic right whale is a migratory species that is usually found within waters of the western North Atlantic between 20° and 60° N latitude. Generally, individuals undergo seasonal coastal migrations from summer feeding grounds off eastern Canada and the U.S. northeast coast to winter calving grounds off the U.S. southeast coast (**Figure 4**).

Recent sightings data also report a few right whales as far as Newfoundland, the Labrador Basin, and southeast of Greenland (Waring et al., 2010; Mellinger et al., 2011). Research results suggest the existence of the following six major congregation areas:

1. Coastal waters of the southeastern U.S.;
2. the Great South Channel;
3. Georges Bank/Gulf of Maine;
4. Cape Cod and Massachusetts Bays;
5. Bay of Fundy; and
6. the Scotian Shelf (Waring et al., 2010).

Only the congregation area within coastal waters of the southeastern U.S. is located within the proposed survey area. Movements of individuals within and between these congregation areas are extensive, and data show distant excursions, including into deep water off the continental shelf (Mate et al., 1997; Baumgartner and Mate, 2005; Mellinger et al., 2011). Using acoustic survey methods, Morano et al. (2012) found that right whales are present in Massachusetts Bay year-round for at least 24% of every month, suggesting that the whales may be using the bay not only as a migratory corridor to and from Cape Cod Bay but also as non-migratory habitat. The North Atlantic Right Whale Sighting Survey (NARWSS) program showed that some individuals may stay in the northern Gulf of Maine during the winter. Further, in 2008 and 2009, right whales were sighted during the NARWSS program off Jeffrey's and Cashes Ledge, Stellwagen Bank, and Jordan Basin from December to February (Khan et al., 2009, 2010). The groupings of individual whales within these congregation areas is likely to be a function of acceptable prey distribution, since they must locate and exploit extremely dense patches of zooplankton to feed efficiently (Mayo and Marx, 1990). These dense zooplankton patches are likely a primary characteristic of the spring, summer, and fall right whale habitats (Kenney et al., 1986, 1995).

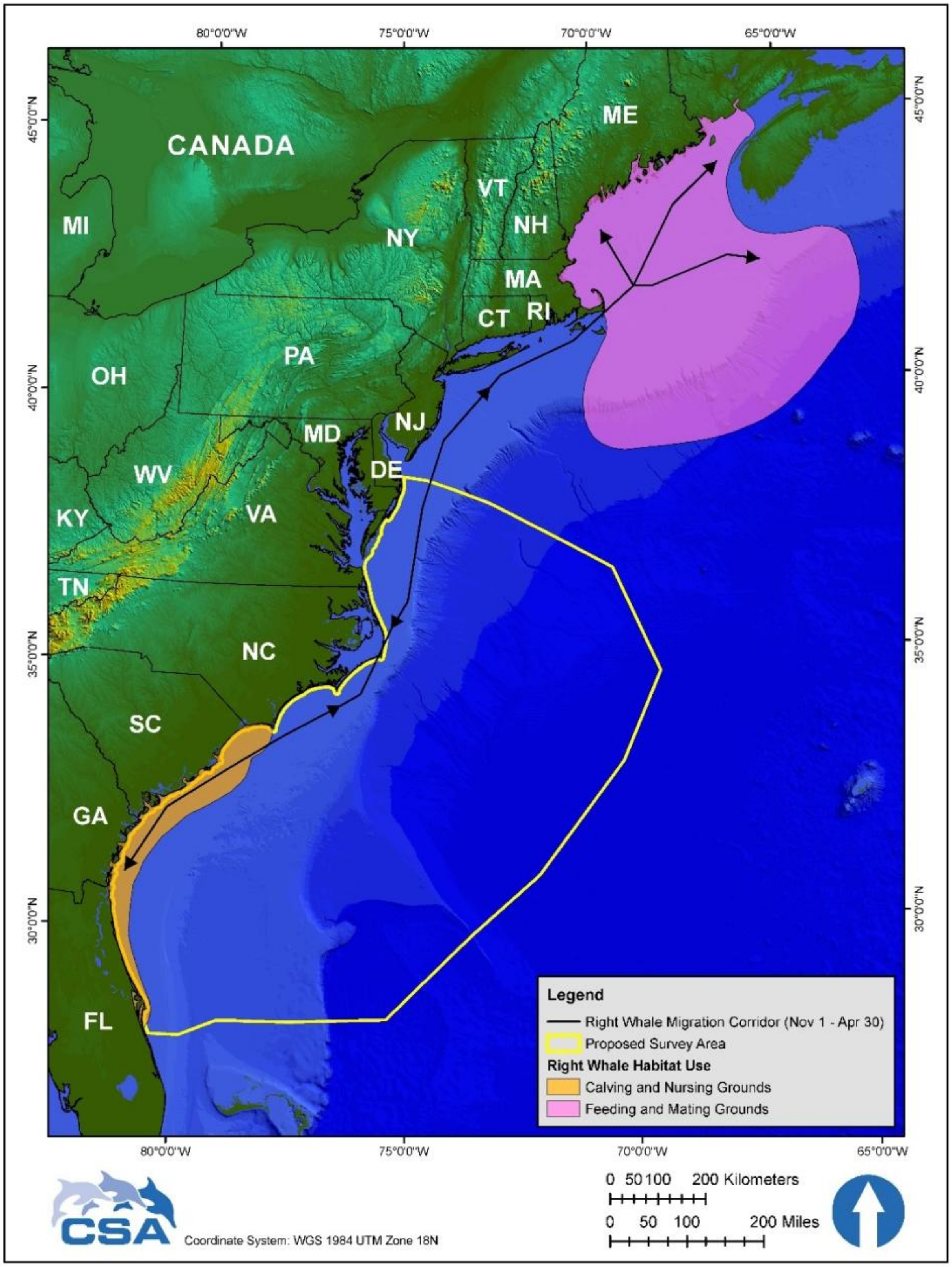

Figure 4. North Atlantic right whale seasonal distribution and habitat use relative to the proposed survey area. (From: National Oceanic and Atmospheric Administration [NOAA] Fisheries Service, Southeast Regional Office, St. Petersburg, FL, http://sero.nmfs.noaa.gov.).

Blue Whale (*Balaenoptera musculus*)

The blue whale is the largest cetacean, although its size range overlaps with that of fin and sei whales. The species is currently divided into five subspecies (Committee on Taxonomy, 2013). The northern hemisphere subspecies (*B. m. musculus*) is known to occur within the proposed survey area. Most adults of this subspecies are 23 to 27 m (75 to 90 ft) in length (Jefferson et al., 2008).

Status

The blue whale is listed as an endangered species, species-wide and range-wide. Blue whales in the North Atlantic were exploited heavily. A full assessment of present status has not been carried out, though available evidence suggests they are increasing in numbers at least in the area of the central North Atlantic though they remain rare in the northeastern Atlantic where they were once common. At present, there are around 1,000 individuals off Iceland and several hundred in the Gulf of St Lawrence (http://iwc.int/status). There are insufficient data to determine the status of the Western North Atlantic stock and population within the U.S. This stock is listed under the MMPA as strategic and depleted under the MMPA because the species is listed as endangered under the ESA (Waring et al., 2010). There is no designated critical habitat for this species within the proposed survey area.

Distribution

The blue whale is considered by NMFS as an occasional visitor in U.S. Atlantic exclusive economic zone (EEZ) waters, which may represent the current southern limit of its feeding range (Waring et al., 2010).

In the western North Atlantic Ocean, the blue whale's range extends from the Arctic to Cape Cod, Massachusetts, although it is frequently sighted off eastern Canada (e.g., Newfoundland) (Waring et al., 2010). Using U.S. Navy asset hydrophone arrays, Clark and Gagnon (2004) identified blue whales as far south as Bermuda (but rarely farther south). Yochem and Leatherwood (1985) suggest an occurrence of this species south to Florida and the Gulf of Mexico. In general, the blue whale's range and seasonal distribution is governed by the availability of prey (USDOC, NMFS, 1998).

Fin Whale (*Balaenoptera physalus*)

The fin whale is the second largest cetacean (USDOC, NMFS, 2010a). It is divided into three subspecies, including the northern fin whale (*B. p. physalus*), southern fin whale (*B. p. quoyi*), and pygmy fin whale (*B. p. patachonica*) (Committee on Taxonomy, 2013). The northern fin whale subspecies is found within the proposed survey area. Adult fin whales in the northern hemisphere may reach a length of approximately 24 m (80 ft).

Status

Fin whales off the eastern U.S. and eastern Canada are believed to constitute a single management stock (Western North Atlantic stock) (Waring et al., 2014). The species is currently listed as endangered under the ESA. The Western North Atlantic stock is classified as strategic and depleted under the MMPA because of its listing under the ESA. There is no designated critical habitat for the fin whale (USDOC, NMFS, 2010a).

Distribution

The fin whale is found primarily within temperate and polar latitudes. Seasonal migration patterns within its range remain undetermined (2010). Fin whales were found present in Bermuda from early September through mid-May (Clark and Gagnon, 2004). Fin whales were also seen in the mid-ocean near the Mid-Atlantic ridge from late fall through early winter. The fin whale is the most common whale sighted in northwest Atlantic waters from Cape Hatteras, North Carolina, to Maine during surveys conducted from 1978 through 1982, with fin whales representing 46% of all sightings (USDOC, NMFS, 2010a; Waring et al., 2014).

Humpback Whale (*Megaptera novaeangliae*)

The humpback whale is robust and medium-sized mysticete, and adults range from 15 to 18 m (50 to 60 ft) in length. Humpback whales are distinguished from all other cetaceans by their long flippers, which are approximately one-third the length of the body (Jefferson et al., 2008). One species of the humpback whale is currently recognized (Committee on Taxonomy, 2013).

Status

Distinct geographic forms of humpback whales are not widely recognized, though genetic evidence suggests there are several subspecies (e.g., North Atlantic, Southern Hemisphere, and North Pacific subspecies) (USDOC, NMFS, 1991; Waring et al., 2014). In 2000, NMFS Atlantic Stock Assessment Team reclassified the western North Atlantic humpback whale as a separate and discrete management stock (Gulf of Maine stock) (Waring et al., 2014).

The humpback whale is currently listed as endangered under the ESA. The Gulf of Maine stock is classified as strategic and depleted under the MMPA because of its listing under the ESA. The NMFS has recently estimated the humpback population in the western North Atlantic as 7,698 individuals (4,894 males and 2,804 females) (Waring et al., 2013). No critical habitat has been designated for the humpback whale.

Distribution

The humpback whale is a cosmopolitan species that may be found from the equator to subpolar latitudes, less commonly in the Arctic. Some individuals are found year-round at certain locations (e.g., Gulf of Maine), while others display highly migratory patterns. Humpback whales are generally found within continental shelf areas and oceanic islands. Most humpback whales in the western North Atlantic Ocean migrate to the West Indies to mate (e.g., Dominican Republic); however, some whales do not make the annual winter migration (Waring et al., 2014). Sightings data show that humpback whales traverse through coastal waters of the southeastern U.S., including the proposed survey area (Waring et al., 2013).

Swingle et al. (1993) and Barco et al. (2002) reported humpback sightings off Delaware Bay and Chesapeake Bay during the winter, which suggests the Mid-Atlantic region may also serve as wintering grounds for some Atlantic humpback whales. This region has also been suggested as important area for juvenile humpbacks (Wiley et al., 1995).

Sei Whale (*Balaenoptera borealis*)

The sei whale is the third largest cetacean (following the blue and fin whales), with adult length ranging from 16 to 20 m (52 to 66 ft). It is very similar in appearance to fin and Bryde's whales. Two subspecies of sei whales are currently recognized (Committee on Taxonomy, 2013). The northern sei whale (*B. b. borealis*) is known to occur within the proposed survey area.

Status

Two management stocks of northern sei whales are recognized within the Atlantic: the Nova Scotia stock and the Labrador Sea stock. The range of the Nova Scotia stock includes the continental shelf waters of the northeastern U.S. and extend northeastward to south of Newfoundland.

The sei whale is currently listed as endangered under the ESA. The Nova Scotia management stock is classified as strategic and depleted under the MMPA because of its listing under the ESA. An abundance estimate of 357 (CV=0.52) sei whales was generated from a shipboard and aerial survey conducted between Central Virginia to lower Bay of Fundy during June–August 2011 (Palka 2012). There is no designated critical habitat for this species.

Distribution

The sei whale is a cosmopolitan and highly migratory species (HMS) that is found from temperate to subpolar regions, but it appears to be more restricted to mid-latitude temperate zones compared to other balaenopterids (*Balaenoptera* spp. and *Megaptera novaeangliae*) (Reeves et al., 2002; Shirihai and Jarrett, 2006; Jefferson et al., 2008). Sei whales are commonly sighted off Nova Scotia, the Gulf of Maine, and Georges Bank in spring and summer (Waring et al., 2014). Data suggest a major portion of the Nova Scotia stock is centered in waters north of the proposed survey area, at least during the feeding season (Waring et al., 2014). Within this range, the sei whale is often found near the continental shelf edge. This general offshore pattern of sei whale distribution is disrupted during episodic incursions into more shallow and inshore waters.

Sperm Whale (*Physeter macrocephalus*)

The sperm whale is the largest odontocete cetacean, with adult length ranging from 12 to 18 m (40 to 60 ft). They are also the most sexually dimorphic whale in body length and weight (Whitehead, 2002). The most distinctive feature of the sperm whale is a massive and specialized nasal complex.

Status

Sperm whales within the northern Atlantic are classified in one management stock (North Atlantic). It remains unresolved whether the northwestern Atlantic population is discrete from the northeastern Atlantic population (Waring et al., 2014).

The sperm whale is currently listed as endangered under the ESA. The Northern Atlantic stock is classified as strategic and depleted under the MMPA because of its listing under the ESA. Shipboard and aerial surveys conducted between June and August 2011 between the Bay of Fundy central Florida resulted in abundance estimates of 1,593 (CV=0.36) sperm whales between central Virginia and the Bay of Fundy, and 695 (CV=0.39) sperm whales conducted concurrently (June-August 2011) in waters between central Virginia and central Florida was generated from a shipboard and aerial survey conducted during Jun–Aug 2011 (Palka, 2012). The best recent abundance estimate for sperm whales entire western North Atlantic is the sum of the 2011 surveys—2,288 (CV=0.28) (Waring et al., 2014). There is no designated critical habitat for this stock (USDOC, NMFS, 2010b).

Distribution

Sperm whales are cosmopolitan in their distribution, ranging from tropical latitudes to pack ice edges in both hemispheres (Jefferson et al., 2008). Generally, only male sperm whales venture to the extreme low latitudes. In the U.S. Atlantic EEZ waters, there appears to be a distinct seasonal cycle (Waring et al., 2014). In winter, sperm whales concentrate east and northeast of Cape Hatteras, North Carolina. In spring, the distribution center moves northward to waters east of Delaware and Virginia but spreads throughout the central portion of the Mid-Atlantic Bight (MAB) to the southern portion of Georges Bank. In summer, the distribution also includes continental slope and shelf waters as far as southern New England. In the fall, sperm whale occurrence on the continental shelf and shelf edge is highest in the MAB.

4.2 NONLISTED MARINE MAMMALS

Bryde's Whale (*Balaenoptera brydei*)

The Bryde's whale is a large mysticete that may reach a length of 16.5 m (54 ft). It is similar in size and appearance to the sei whale.

Status

Bryde's whales within the northwest Atlantic are not classified within a management stock. The species is not listed as threatened or endangered under the ESA.

Distribution

Bryde's whales have a circumglobal distribution in tropical and subtropical waters. In the western Atlantic Ocean, Bryde's whales are reported from off the southeastern U.S. (Virginia to Florida) and through the southern West Indies to Cabo Frio, Brazil (Cummings, 1985; Waring et al., 2013). The southeastern U.S., including the proposed survey area, is considered to be a "secondary range" for this species (Jefferson et al., 2008).

Common Minke Whale (Balaenoptera acutorostrata acutorostrata)

The minke whale is a small mysticete that is divided into two species: the common minke whale and the Antarctic minke whale. The common minke whale is further divided into three subspecies (Committee on Taxonomy, 2013). The subspecies *B. a. acutorostrata* occurs within the North Atlantic. Adult common minke whales reach a length of 8.8 m (29 ft) (Jefferson et al., 2008).

Status

Minke whales off the eastern coast of the U.S. are included within the Canadian East Coast stock, which ranges from the Davis Strait, Canada (45º W), to the Gulf of Mexico (Waring et al., 2014). There are insufficient data to determine the status of minke whales in the U.S. Atlantic EEZ. It is not listed as endangered under the ESA, and the stock is not classified as strategic or depleted under the MMPA. An abundance estimate of 2,591 (CV=0.81) minke whales was generated from a shipboard and aerial survey conducted between central Virginia to the lower Bay of Fundy during June-August 2011 (Palka 2012).

Distribution

The minke whale has a cosmopolitan distribution and occurs in polar, temperate, and tropical waters. Minke whales are generally found within waters of the continental shelf. It is considered common within the U.S. Atlantic EEZ during summer months and largely absent during winter, although sightings data suggest its distribution within this area is largely centered in New England and Canadian waters north of the proposed survey area) (Waring et al., 2014). However, recent acoustic data (Norris et al, 2013, Risch et al 2013) suggest that minke whales may be present within the South Atlantic Bight year round with increased densities during the winter months.

Beaked Whales

Six species of whales of the family Ziphiidae may occur within the proposed survey area. These include one species of the genus *Hyperoodon* (Northern bottlenose whale [*H. ampullatus*]), one species of the genus *Ziphius* (Cuvier's beaked whale [*Z. cavirostris*]) and four species of the genus *Mesoplodon* (Blainville's beaked whale [*M. densirostris*], Gervais' beaked whale [*M. europaeus*], Sowerby's beaked whale [*M. bidens*], and True's beaked whale [*M. mirus*]). Beaked whales are medium-sized cetaceans with body lengths of 4.6 to 10 m (15 to 33 ft) characterized by reduced dentition, elongated rostrum, and accentuated cranial vertex (associated with sound production and modification) (Jefferson et al., 2008). *Mesoplodon* beaked whales are difficult to identify to the species level at sea, and much of the available characterization for them is to genus level only (Waring et al., 2013).

Status

All beaked whale species known to occur within the northwest Atlantic are not listed as threatened or endangered under the ESA or classified as strategic or depleted stocks under the MMPA (Waring et al., 2014). Each species is separated into separate management stocks (Western North Atlantic) (Waring et al., 2014; Waring et al., 2008).

The total number of northern bottlenose whales off the eastern U.S. and Canadian Atlantic coast is unknown, and seasonal abundance estimates are not available for this stock. The best abundance estimate for *Mesoplodon* spp. beaked whales is the pooled sum of all species from the 2011 Central Florida to lower Bay of Fundy survey estimates – 7,092 (CV=0.54) (Waring et al., 2014). The best abundance estimate for

Cuvier's beaked whales is the sum of the 2011 Central Florida to lower Bay of Fundy surveys—6,532 (CV=0.32).

Distribution

Northern bottlenose whales are considered as extremely uncommon or rare in waters of the U.S. Atlantic Exclusive Economic Zone (Waring et al., 2008). Cuvier's and *Mesoplodon* spp. beaked whale sightings within the northwest Atlantic during shipboard and aerial surveys have usually been along the continental shelf edge in the Mid-Atlantic region between Nova Scotia and central Florida, primarily in late spring and summer (Waring et al., 2014). Along the Atlantic coast of the U.S., beaked whales may be associated with the Gulf Stream and warm-core eddies (Waring et al., 2001).

Stenella Dolphins

Five species of oceanic dolphins of the genus *Stenella* occur within the northwestern Atlantic. These include the pantropical spotted dolphin (*S. attenuata*), striped dolphin (*S. coeruleoalba*), Clymene dolphin (*S. clymene*), Atlantic spotted dolphin (*S. frontalis*), and spinner dolphin (*S. longirostris*). *Stenella* body length ranges between 1.7 and 2.6 m (5.6 and 8.5 ft) (Jefferson et al., 2008).

Status

Each western Atlantic *Stenella* species is managed as a separate Western North Atlantic stock. None of these species are listed as threatened or endangered under the ESA, and none of the management stocks are classified as strategic or depleted under the MMPA (Waring et al., 2014).

Distribution

The five species of western Atlantic *Stenella* occur within both coastal and oceanic waters from 40°S to 40°N latitude (Perrin and Gilpatrick, 1994; Perrin and Hohn, 1994). Atlantic spotted, pantropical spotted, Clymene, and spinner dolphins are distributed primarily in tropical and subtropical waters, whereas the distribution of striped dolphins extends from tropical to temperate waters (Jefferson et al., 2008). Generally, *Stenella* occur along the continental shelf edge and slope within their range. The Atlantic spotted dolphin, however, may also occur on the continental shelf in some areas, including the proposed survey area (Jefferson et al., 2008; Waring et al., 2014).

Pygmy and Dwarf Sperm Whales (*Kogia breviceps* and *K. sima*)

Pygmy (*Kogia breviceps*) and dwarf (*K. sima*) sperm whales are small cetaceans with blunt squarish heads and underslung lower jaws, similar to the sperm whale. Pygmy sperm whales attain body lengths of approximately 4 m (13 ft), whereas dwarf sperm whales reach lengths of approximately 3 m (10 ft) (Jefferson et al., 2008).

Status

Pygmy and dwarf sperm whales are difficult to differentiate at sea (Caldwell and Caldwell, 1989; Würsig et al., 2000), and sightings of either species are often categorized as *Kogia* sp. Each species within the western North Atlantic are placed within separate stocks. The stocks are not classified as strategic or depleted under the MMPA.

There are insufficient data to determine the population status of each *Kogia* sp. in the western U.S. Atlantic EEZ. The best abundance estimate for combined species (*Kogia* spp.) is 3,785 (CV=0.47; Table 1). This estimate is from summer 2011 surveys covering waters from central Florida to the lower Bay of Fundy (Waring et al., 2014).

Both species are not listed as endangered or threatened under the ESA, and the Western North Atlantic stock is not considered strategic under the MMPA. There is insufficient information with which to assess population trends (Waring et al., 2014).

Distribution

Dwarf and pygmy sperm whales appear to be distributed worldwide in temperate to tropical waters (Caldwell and Caldwell, 1989; McAlpine, 2002). Sightings of these animals in the western North Atlantic occur in oceanic waters between Maine and central Florida (Waring et al., 2014).

Harbor Porpoise (*Phocoena phocoena*)

The harbor porpoise is the only porpoise species found in the Atlantic. It is a small, stocky cetacean with a blunt, short-beaked head. There are four subspecies, with *P. p. phocoena* in the North Atlantic (Committee on Taxonomy, 2013). This subspecies reaches a body length of 1.9 m (6 ft) (Jefferson et al., 2008).

Status

The Gulf of Maine/Bay of Fundy stock of harbor porpoise is found in U.S. and Canadian Atlantic waters. It is not listed as threatened or endangered under the ESA; however, it is classified as a strategic stock and depleted under the MMPA (Waring et al., 2014).

Distribution

The harbor porpoise is usually found in shallow waters of the continental shelf, although they occasionally travel over deeper offshore waters. Waring et al. (2014) reports that harbor porpoises are generally concentrated along the continental shelf within the northern Gulf of Maine and southern Bay of Fundy region during summer months (July to September). During fall (October to December) and spring (April to June), they are widely dispersed from New Jersey to Maine. During winter (January to March), they range from New Brunswick, Canada, to North Carolina.

Bottlenose Dolphin (*Tursiops truncatus*)

Adult bottlenose dolphins range in length from 1.8 to 3.8 m (5.9 to 12.5 ft). Within the western North Atlantic, including the proposed survey area, there are two distinct bottlenose dolphin forms, or ecotypes: coastal and offshore. The two forms are genetically and morphologically distinct, though regionally variable (Jefferson et al., 2008).

Status and Distribution

The bottlenose dolphin is not listed as threatened or endangered under the Endangered Species Act. Bottlenose dolphins within the western North Atlantic are separated into 13 management stocks, consisting of three migratory population stocks and 10 resident population stocks, as listed below:

- Migratory Stocks
  - Western North Atlantic Offshore Stock;
  - Northern Coastal Migratory Stock;
  - Southern Coastal Migratory Stock;
- Resident Population Stocks
  - South Carolina-Georgia Coastal Resident Stock;
  - Northern Florida Coastal Resident Stock;
  - Central Florida Coastal Resident Stock;
  - Northern North Carolina Estuarine System Stock;
  - Southern North Carolina Estuarine System Stock;
  - Northern South Carolina Estuarine System Stock;
  - Charleston Estuarine System Stock;
  - Northern Georgia / Southern South Carolina Estuarine System Stock;
  - Southern Georgia Estuarine System Stock;

- Jacksonville Estuarine System Stock; and
- Indian River Lagoon Estuarine System Stock.

The Western North Atlantic Offshore stock primarily includes offshore forms (ecotypes) and is distributed primarily along the outer continental shelf and continental slope in the northwest Atlantic Ocean (Waring et al., 2014). The offshore stock is not considered strategic or depleted under the MMPA.

The differentiation of the coastal stocks of bottlenose dolphins are based on genetic differences (Waring et al., 2014 Coastal stocks are in most cases composed of coastal form dolphins; however, in discrete areas South of Cape Lookout (North Carolina) the coastal form occurs in relatively lower densities over the continental shelf (waters between 20 m and 100 m depth) than other locations and overlaps spatially with the offshore form. Coastal migratory stock dolphins are expected to occur within the proposed survey area. The ranges of the migratory and coastal resident stocks within or adjacent to the proposed survey area are shown in **Figure 5**.

Several studies support a distinction between resident coastal form dolphins inhabiting nearshore (inner shelf) waters and those inhabiting inshore waters of bays, sounds and estuaries (Caldwell 2001; Gubbins 2002a; Zolman 2002; Gubbins et al. 2003; Mazzoil et al. 2005; Litz et al. 2012),

The degree of spatial overlap between these resident estuarine and coastal populations, and movement of these populations on seasonal or shorter time scales is unclear (Waring et al., 2014). Photo-identification studies within certain estuaries have demonstrated seasonal immigration and emigration, and the presence of transient animals (Speakman et al. 2006), nevertheless, for the purposes of stock definition, bottlenose dolphins that inhabit primarily estuarine habitats are considered distinct from those that inhabit coastal habitats (Waring et al., 2014). Survey data suggest that the currently recognized estuarine stock dolphins are generally restricted to waters within approximately 3 km from shore (Waring et al., 2014). Therefore, it is not likely that animals from these stocks would occur within the proposed survey area.

All coastal form stocks, including coastal migratory, and coastal resident and estuarine system stocks have been designated as strategic and depleted under the MMPA but are not listed as threatened or endangered under the ESA (Waring et al., 2014).

Unusual Mortality Event (UME)

Under the MMPA, NMFS declared an Unusual Mortality Event (UME) for bottlenose dolphins in the Mid-Atlantic region from early July 2013 through the present. Elevated numbers of strandings of this species have occurred in New York, New Jersey, Delaware, Maryland, and Virginia, with the highest number of strandings to date occurring in Virginia. All age classes of bottlenose dolphins are involved, and strandings range from a few live animals to mostly dead animals with many very decomposed. A team of independent scientists is working with the Working Group on Marine Mammal UME to review the data collected. Currently, no single cause for this stranding can be identified. Some dolphins have shown pulmonary lesions, and one dolphin has tested for possible morbillivirus infection, although it is too early to determine if morbillivirus is causing the strandings.

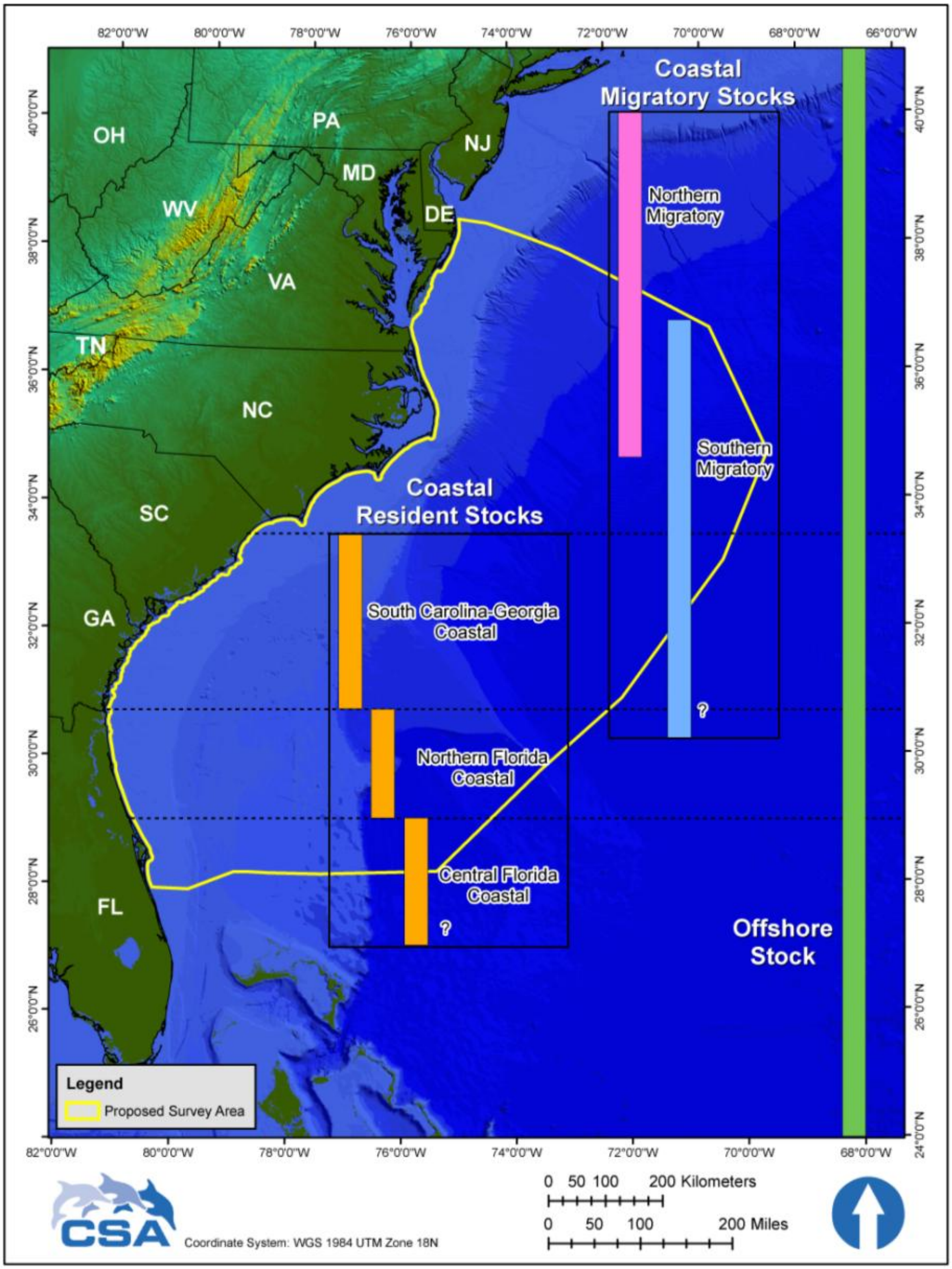

Figure 5. Latitudinal distribution of Western North Atlantic bottlenose dolphin stocks, relative to the proposed survey area. The positions of the distributional bars do not indicate offshore distributions. (Adapted from: USDOC, NMFS, 2013.)

Killer Whale (*Orcinus orca*)

Killer whales within the western North Atlantic are included within the Western North Atlantic stock. They are considered uncommon or rare in waters of the U.S. Atlantic EEZ (Katona et al., 1988). Adults reach a body length of 9.8 m (32 ft) (Jefferson et al., 2008).

Status

There are insufficient data to determine the population status of killer whales in U.S. Atlantic EEZ (Waring et al., 2000). The species is not listed as threatened or endangered under the ESA, and the Western North Atlantic stock is not classified as a strategic stock (Waring et al., 2000).

Distribution

The killer whale's distribution is cosmopolitan (Jefferson et al., 2008). Within the North Atlantic, its range extends from the Arctic ice-edge to the West Indies. While their occurrence is unpredictable in the U.S. Atlantic EEZ, they do occur in fishing areas, perhaps coincident with tuna, in warm seasons (Katona et al., 1988; USDOC, NMFS, 1995). In an extensive analysis of historical whaling records, Reeves and Mitchell (1988) plotted the distribution of killer whales in offshore and mid-ocean areas. Their results suggest that the offshore areas need to be considered in present-day distribution, movements, and stock relationships. Stock definition is unknown. Results from other areas (e.g., the Pacific Northwest and Norway) suggest that social structure and territoriality may be important.

Pygmy Killer Whale (*Feresa attenuata*)

Pygmy killer whales are considered uncommon or rare in waters of the U.S. Atlantic EEZ (Waring et al., 2010). Adults attain a body length of up to 2.6 m (8.5 ft) (Jefferson et al., 2008).

Status

Pygmy killer whales within the western North Atlantic are included within the Western North Atlantic stock. There are insufficient data to determine the status of pygmy killer whales in the U.S. Atlantic EEZ. It is assumed that the paucity of sightings of this species within the western North Atlantic is due to a naturally low number of groups compared to other cetacean species (Waring et al., 2007). The species is not listed as threatened or endangered under the ESA, and the Western North Atlantic stock is not a classified as strategic stock under the MMPA (Waring et al., 2014).

Distribution

The pygmy killer whale is distributed worldwide in tropical to subtropical waters (Jefferson et al., 2008). A group of six individuals was sighted during a 1992 vessel survey off of Cape Hatteras, North Carolina, in waters greater than 4,920 ft (1,500 m) deep (Hansen et al., 1994), but the whales were not encountered again during subsequent surveys (USDOC, NMFS, 1999, 2002; Mullin and Fulling, 2003).

False Killer Whale (*Pseudorca crassidens*)

The false killer whale is a large, dark gray to black dolphin that has a long, slender body form with a small conical head. Adults may reach a body length of up to 6 m (20 ft) (Jefferson et al., 2008).

Status

False killer whales that inhabit the western North Atlantic are not included within a separate MMPA management stock. There are insufficient data to determine its status within this region.

Distribution

False killer whales are distributed worldwide within tropical to warm temperate waters. Generally, they are found in deep oceanic areas, though they are known to also occur on the continental shelf and shelf edge (Baird, 2002; Jefferson et al., 2008).

Risso's Dolphin (*Grampus griseus*)

Risso's dolphins are large dolphins with characteristic blunt head and light coloration, often with extensive scarring. Adults reach body lengths of over 3.8 m (12.5 ft).

Status

The status of the Western North Atlantic stock of the Risso's dolphin in the U.S. Atlantic EEZ is not well documented. An abundance estimate of 18,250 (CV=0.46) Risso's dolphins was generated from a shipboard and aerial survey conducted between central Florida to the lower Bay of Fundy during June-August 2011 (Palka 2012). Risso's dolphins are not listed as threatened or endangered under the ESA and the Western North Atlantic stock is not considered strategic under the MMPA.

Distribution

Risso's dolphins are widely distributed in tropical and temperate seas. In the Northwest Atlantic they occur from Florida to eastern Newfoundland (Leatherwood et al., 1976; Baird and Stacey, 1990). Risso's dolphins occur along the continental shelf edge from Cape Hatteras to Georges Bank during spring, summer, and autumn. In winter, they occur in oceanic (slope) waters within the MAB (Waring et al., 2014). The majority of sightings during the 2011 surveys occurred along the continental shelf break with generally lower sighting rates over the continental slope (Palka 2012).

Pilot Whales (*Globicephala macrorhynchus* and *G. melas*)

Two species of pilot whales occur within the western North Atlantic: the short-finned pilot whale (*Globicephala macrorhynchus*) and the long-finned pilot whale (*G. melas*). These species are difficult to differentiate at sea and so they are often reported as *Globicephala* sp. Pilot whales attain a body length of 7.2 m (24 ft) (short-finned pilot whale) and 6.7 m (22 ft) (long-finned pilot whale) (Jefferson et al., 2008).

Status

There are insufficient data to determine the status of short-finned and long-finned pilot whales in the U.S. Atlantic EEZ. Each species within this area is categorized into the Western North Atlantic stock. Neither species is listed under the ESA, nor are their Western North Atlantic stocks classified as strategic.

Distribution

Pilot whales in the U.S. Atlantic EEZ occur in oceanic waters. Short-finned pilot whales are found within warm temperate to tropical waters and, within the North Atlantic, generally do not range farther north than 50°N latitude. Long-finned pilot whales occur in temperate and subpolar waters, with some distributional overlap with short-finned pilot whales in their southern range. Within the western North Atlantic, short-finned pilot whale strandings have been reported as far north as Nova Scotia (1990) and Block Island, Rhode Island (2001), though the majority of the strandings occurred from North Carolina southward. Long-finned pilot whales have been reported stranded as far south as Florida The latitudinal ranges of the two species therefore remain uncertain; however, it is expected that most pilot whale sightings that are made south of Cape Hatteras are short-finned pilot whales, while sightings that are made north of approximately 42°N are long-finned pilot whales (Waring et al., 2014).

Short-beaked Common Dolphin (*Delphinus delphis*)

The common dolphin may be one of the most widely distributed species of cetaceans, as it is found worldwide in temperate, tropical, and subtropical seas. Two species have been recognized: the long-beaked common dolphin (*Delphinus capensis*) and the short-beaked common dolphin; however the short-beaked common dolphin is the only species that occurs within the northern Atlantic. Common dolphins attain a body length of 2.5 m (8.2 ft) (Jefferson et al., 2008).

Status

Short-beaked common dolphins within the northwestern Atlantic are classified within one stock (Western North Atlantic stock) under the MMPA (Waring et al., 2014). Their status in the U.S. Atlantic EEZ is not well documented. The species is not listed as threatened or endangered under the ESA, and there are insufficient data to determine the population trends for this species. It is not classified as a strategic or depleted stock.

Distribution

Common dolphins are distributed in waters off the northeastern U.S. coast (Cetacean and Turtle Assessment Program [CETAP], 1982; Selzer and Payne, 1988; Waring et al., 1992; Hamazaki, 2002). They regularly occur along the continental shelf and slope (100 to 2,000 m [328 to 6,562 ft]) from 50ºN to Cape Hatteras, North Carolina, although aggregations have been reported as far south as eastern Florida (Gaskin, 1992). They occur from Cape Hatteras northeast to Georges Bank (35° to 42° N) during mid-January to May and move as far north as the Scotian Shelf from mid-summer to autumn (Selzer and Payne, 1988).

Melon-headed Whale (*Peponocephala electra*)

The melon-headed whale is a small, robust whale that reaches a maximum length of about 2.8 m (9 ft) (Jefferson et al., 2008).

Status

The western North Atlantic population of melon-headed whales is considered a separate stock. There are insufficient data to determine the population status of the stock in the western North Atlantic EEZ, it is not classified as a strategic stock, nor is it listed as threatened or endangered under the ESA (Waring et al., 2007).

Distribution

The melon-headed whale is distributed worldwide in tropical to subtropical waters and is assumed to be part of the cetacean fauna of the tropical western North Atlantic (Jefferson et al., 1994). The numbers of melon-headed whales off the northwest Atlantic coast are unknown, and seasonal abundance estimates are not available (Waring et al., 2014). The paucity of sightings is probably because of a naturally low number of groups compared to other cetacean species (Waring et al., 2007).

Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*)

The Atlantic white-sided dolphin is robust and attains a body length of approximately 2.8 m (9 ft) (Jefferson et al., 2008). It is characterized with a strongly “keeled” tail stock and distinctive color pattern.

Status

Atlantic white-sided dolphins observed off the U.S. eastern coast are classified within the Western North Atlantic stock. However, the distribution of sightings, strandings, and incidental takes suggest the possible existence of three stock units within this region: Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea stocks (Waring et al., 2014). There are insufficient data to determine seasonal abundance estimates of Atlantic white-sided dolphins off the U.S. eastern coast and their status in the U.S. Atlantic EEZ. The species is not listed as threatened or endangered under the ESA, and the stock is not classified as strategic.

Distribution

Atlantic white-sided dolphins are found in cold temperate and subpolar waters of the North Atlantic (Cipriano, 2002). Their preferred habitat appears to be waters of the outer continental shelf and slope, although there are regular sightings of this species within the western North Atlantic waters along the mid-shelf to the 100-m (328-ft) depth contour (Waring et al., 2013). The Western North Atlantic stock inhabits waters from central West Greenland to North Carolina (about 35°N) (Waring et al., 2014).

White-beaked Dolphin (*Lagenodelphis albirostris*)

White-beaked dolphins are relatively small delphinids. They are about 8-10.5 ft (2.4-3.2 m) in length and weigh 395-770 lbs (180-350 kg) (Jefferson *et al.* 2008).

Status

Atlantic white-beaked dolphins observed off the U.S. eastern coast are classified within the Western North Atlantic stock. The status of white-beaked dolphins in U.S. Atlantic coast waters is unknown. The species is not listed as threatened or endangered under the ESA and the stock is not classified as depleted or strategic under the MMPA (Waring et al., 2007).

Distribution

White-beaked dolphins have a broad distribution throughout the temperate waters of the North Atlantic Ocean, from about 40-80° North. They generally prefer shallow waters less than 200 m (656 ft) deep (Jefferson *et al*. 2008). Based on existing sightings records, they would be considered as rare within the proposed survey area (Waring et al., 2007).

Fraser's Dolphin (*Lagenodelphis hosei*)

Fraser's dolphins are characterized by an extremely robust body and small appendages. Maximum length is approximately 2.7 m (9 ft) (Jefferson et al., 2008).

Status

There are insufficient data to determine the status of the Western North Atlantic stock of Fraser's dolphins in the U.S. Atlantic EEZ or population trends for this species. The species is not listed as threatened or endangered under the ESA. It is not classified as a strategic stock.

Distribution

Fraser's dolphins are distributed worldwide within tropical, oceanic waters between 30°N and 30°S latitude. They may also occur closer to shore in areas where deep water approaches the coast (Dolar, 2002; Jefferson et al., 2008). The paucity of Fraser's dolphin sightings within the western North Atlantic during historic survey efforts is attributed to naturally low abundance compared to other cetacean species (Waring et al., 2007).

Rough-Toothed Dolphin (*Steno bredanensis*)

The rough-toothed dolphin is a relatively robust dolphin that attains a body length of 2.8 m (9 ft) (Jefferson et al., 2008). It is characterized by a long, conical head with no demarcation between the melon and beak.

Status

Rough-toothed dolphins observed off the U.S. eastern coast are classified within the Western North Atlantic stock. There are insufficient data to determine seasonal abundance estimates of rough-toothed dolphins off the U.S. eastern coast or their status in the U.S. Atlantic EEZ. The species is not listed as threatened or endangered under the ESA, and the stock is not classified as strategic or depleted under the MMPA (Waring et al., 2014).

Distribution

Rough-toothed dolphins are distributed within tropical and subtropical waters between 40°N and 35°S latitude. Records from the Atlantic are mostly from between the southeastern U.S. and southern

Brazil (Jefferson, 2002). They are reported from a wide range of water depths, from shallow, nearshore waters to oceanic waters (West et al. 2011). Most shipboard sightings from the U.S. East Coast, however, have occurred in oceanic waters at depths greater than 1,000 m (Waring et al., 2014).

Seals

The mammalian suborder Pinnipedia includes the following three recognized families:

- Phocidae (earless seals or true seals);
- Otaridae (eared or fur seals and sea lions); and
- Odobenidae (walrus).

Four species of phocid seals may occur within the proposed survey area. Listed in alphabetical order, these include the gray seal (*Halichoerus grypus)*, harbor seal (*Phoca vitulina*), harp seal (*Phoca groenlandica*), and hooded seal (*Cystophora cristata*). Generally, the normal range of the harp and hooded seals is north of the survey area. Over the last decade, increases in pinniped sightings and stranding events have been documented in Mid-Atlantic areas, including the proposed survey area where, historically, records were very few. The increases in sighting and stranding events in these areas suggest that the distributions of these species may be expanding into areas outside of their documented ranges (National Oceanic and Atmospheric Administration [NOAA] Northeast Stranding Network, unpublished pinniped stranding records for New Jersey, Delaware, Maryland, and Virginia, 2007-2011).

Status

Each of the four seal species known to occur within the western North Atlantic and the proposed survey area is classified within separate Western North Atlantic stocks. Currently, there are insufficient data to determine the status of these seal stocks in the U.S. Atlantic EEZ. The species are not listed as threatened or endangered under the ESA, and none of the stocks are classified as strategic.

Distribution

The gray seal ranges from Canada to New York; however, there are strandings records as far south as Cape Hatteras (Davies, 1957; Mansfield, 1966; Katona et al., 1993; Lesage and Hammill, 2001). Gray seal strandings were highest of the four species in the proposed survey area between 2007 and 2011, with 205 records on coastlines between Delaware and Virginia (NOAA Northeast Stranding Network, unpublished pinniped stranding records for New Jersey, Delaware, Maryland, and Virginia, 2007-2011).

The harbor seal is found in all nearshore waters of the Atlantic Ocean and adjoining seas north of 30°N (Katona et al., 1993). In the western North Atlantic, they are distributed from eastern Canada to southern New England and New York, and occasionally to the Carolinas (Mansfield, 1967; Boulva and McLaren, 1979; Katona et al., 1993; Gilbert and Guldager, 1998; Baird, 2001). Within the northern extent of the proposed survey area (between Delaware and Virginia), there were 161 harbor seal strandings between 2007 and 2011 (NOAA Northeast Stranding Network, unpublished pinniped stranding records for New Jersey, Delaware, Maryland, and Virginia, 2007-2011).

The harp seal occurs throughout much of the North Atlantic and Arctic Oceans (Ronald and Healey, 1981). They are divided into three separate stocks, with the largest stock located off eastern Canada (Waring et al., 2012). Harp seals are highly migratory (Sergeant, 1965; Stenson and Sjare, 1997). Within the northern extent of the proposed survey area(between Delaware and Virginia), there were 180 harp seal strandings between 2007 and 2011 (NOAA Northeast Stranding Network, unpublished pinniped stranding records for New Jersey, Delaware, Maryland, and Virginia, 2007-2011).

The hooded seal occurs throughout much of the North Atlantic and Arctic Oceans (King, 1983), preferring deeper water and occurring farther offshore than harbor seals (Sergeant, 1976; Campbell, 1987; Lavigne and Kovacs, 1988; Stenson et al., 1996). Individuals may wander widely, with sightings records as far south as Puerto Rico (Mignucci-Giannoni and Odell, 2001). There are increased occurrences of hooded seals from Maine to Florida in summer and autumn (McAlpine et al., 1999; Harris et al., 2001;

Mignucci-Giannoni and Odell, 2001). However, there were only five recorded strandings of hooded seals within the northern extent of the proposed survey area (between Delaware and Virginia) between 2007 and 2011 (NOAA Northeast Stranding Network, unpublished pinniped stranding records for New Jersey, Delaware, Maryland, and Virginia, 2007-2011).

5.0 TYPE OF INCIDENTAL TAKE REQUESTED

The type of incidental taking authorization that is being requested (i.e., takes by harassment only; takes by harassment, injury and/or death) and the method of incidental taking.

Spectrum requests an IHA pursuant to Section 101 (a)(5)(D) of the MMPA for incidental take by harassment during its planned 2D seismic survey program in the Northwest Atlantic Ocean within the Mid- and South Atlantic Outer Continental Shelf (OCS) Planning Areas, scheduled to occur between February 2016 and July 2016. Proposed seismic operations, as outlined in **Section 1.0**, have the potential to negatively impact marine mammals within the survey area from sounds generated by the seismic source (airgun arrays) during the survey and by vessel operations. It is anticipated that Level A (potential to injure) and Level B (behavioral disruption) harassment (incidental take), as currently defined by NMFS, may result when marine mammals near the proposed activities are exposed to the pulsed sounds generated by the airguns or continuous sounds produced by the survey vessel. No lethal or take by serious injury is anticipated, given the nature of the planned operations and the mitigation measures that are planned (**Sections 11.0** and **13.0**); however, the potential for the onset of temporary threshold shift (TTS) and permanent threshold shift (PTS) is possible. TTS is the mildest form of hearing impairment that can occur during exposure to loud sound and it is not considered to represent physical injury. It is; however, an indicator that physical injury (PTS) is possible if an animal is exposed to higher levels of sound or longer duration of sound. Behavioral reactions (Level B harassment), such as avoidance and temporary displacement behavior are likely for some individual or groups of marine mammals near the seismic source vessel. It is expected that the severity of behavioral effects will vary with the species of marine mammal, the behavior of the animal at the time of reception of the stimulus, as well as the distance and received level of the sound.

6.0 NUMBERS OF MARINE MAMMALS THAT MIGHT BE TAKEN

By age, sex, and reproductive condition (if possible), the number of marine mammals (by species) that may be taken by each type of taking identified in paragraph (a)(5) of this section, and the number of times such takings by each type of taking are likely to occur.

The range of potential effects from noise, in order of decreasing severity and modified slightly from the four zones initially outlined by Richardson et al. (1995), includes death; non-auditory physiological effects; auditory injury/permanent hearing threshold shift; masking; and stress and disturbance, including behavioral response and temporary threshold shift (Richardson et al., 1995; NRC, 2003, 2005; Nowacek et al., 2004; Southall et al., 2007). The more severe potential effects (e.g., temporary or permanent hearing loss) could occur when exposure is close to a sound source (i.e., the magnitude and probability of some effects decrease with increasing distance from a sound source) and when duration of the exposure(s) is longer. Survey protocols and underwater noise mitigation procedures (**Section 11.0**), including using professional PSOs which will optimize marine mammal detection, would be implemented to decrease the potential for any marine mammal to be within the acoustic exclusion zone of the operating airgun array, thereby avoiding the highest sound levels and the potential for masking or potential injury (DON, 2012). However, there is still potential for significant behavioral responses from marine mammals beyond the 500 m exclusion zone (Hermannsen et al., 2015).

Exposures to noise at or above criteria thresholds must occur within the context of the species vulnerability at the time of exposure (Nachtigall and Supin 2014) and be of sufficient duration in order for that exposure to result in injury. In addition, current science indicates that some marine mammals have shown some avoidance reactions to airguns, with some reacting by deviating from migration routes and interrupting feeding activities to move away from the sound; while others show no obvious avoidance or behavior changes but may still be affected by the sound (Nowacek et al., 2007; Southall et al., 2007; Clark et al., 2009). These avoidance reactions by some marine mammals, along with the mitigation measures implemented (visual and passive acoustic monitoring, ramp ups, and shut downs when mammals are detected within or approaching the exclusion zone), would reduce the risk of exposure of marine mammals to intense noise levels. In addition, due to movement of the survey vessel and this avoidance reaction most marine mammals would not be expected to be exposed to noise levels high enough for sufficient time periods to cause more than TTS in most incidences. However, since some mammals that would get and remain close to an airgun array (e.g., bow riding dolphins, animals not detected by PSO's or PAM) might incur TTS, some science has shown that there is the possibility that some individuals occurring very close to airguns might incur PTS (Richardson et al. 1995; Gedamke et al. 2011).

In addition, due to the intermittent nature of airgun sound and since seismic airgun surveys occur in open ocean areas where highly motile cetaceans may move freely to avoid the relatively slow-moving sound source; marine mammal exposures would predominantly be avoided at injurious sound levels and even levels that could negatively affect behavior. Further, the survey would be performed in a systematic fashion along preplotted transects, so it is presumed that exposure to elevated sound would be somewhat localized and temporary in duration; thereby, reducing the potential for impacts.

Section 7 provides a detailed discussion of the modeling performed; Level A and Level B exposure estimates based on existing regulatory criteria, SEL potential injury criteria (Southall et al., 2007); consideration of the NOAA Draft acoustic thresholds for onset of PTS (NOAA, 2015); and effects of acoustic sound on marine mammals. In addition, **Appendix A** provides the Acoustic Propagation and Animal Acoustic Exposure Modeling Report prepared by Marine Acoustics Inc. (MAI). Based on the modeling included in **Appendix A**, the potential for MMPA incidental harassment Level A (injury) exposures was determined with the dual Southall et al. (2007) M-weighted SEL and unweighted peak SPL criteria and mitigation. All values for unweighted peak SPL criteria were zero.

Based on the above, the Level A and Level B exposures calculated and presented in **Section 7,** best available science shifting sound impacts from an unweighted SPL criteria basis to SEL criteria basis that are frequency weighted with functions specific to hearing groups, the radii to the 180- and 160 dB isopleth using the NOAA draft guidance, the implementation of mitigation measures, and animal avoidance reactions; no Level A takes that will cause harm to marine mammals are anticipated; however, as a precaution, the requested Level A and Level B precautionary takes are included in **Table 4**. The Level A requested takes are derived from the Southall et al. (2007) SEL estimates presented in **Section 7.4.3** with the large species that have high sightability by PSOs (i.e., North Atlantic right whale, humpback whale, and Risso's dolphin) not requested for take since these animals are easily sighted by PSOs; and therefore, there would not be exposures to these marine mammals above the 180 dB threshold with the implementation of mitigation measures (i.e., exclusion zone monitoring). The detailed discussion of the basis for this request is included in **Section 7**.

Table 4. Requested Level A and Level B Precautionary Take Estimates.

Species	Level A requested Takes	Level B requested Takes
Minke whale	0	1
Sei whale	0	1
Bryde's whale	0	1
Blue whale	0	1
Fin whale	0	1
North Atlantic right whale	1	1
Humpback whale	1	3
Common dolphin	4	585
Pygmy killer whale	0	0
Short-finned pilot whale	0	413
Long-finned pilot whale	0	76
Risso's dolphin	1	263
Northern bottlenose whale	0	0
Pygmy sperm whale	0	1
Dwarf sperm whale	0	3
Atlantic white-sided dolphin	0	4
Fraser's dolphin	0	0
Sowerby's beaked whale	0	0
Blainville's beaked whale	0	10
Gervais' beaked whale	0	10
True's beaked whale	0	10
Killer whale	0	1
Melon-headed whale	0	0
Harbor porpoise	0	2
Sperm whale	0	51
False killer whale	0	0
Pantropical spotted dolphin	0	114
Clymene dolphin	0	54
Striped dolphin	1	727
Atlantic spotted dolphin	7	934
Spinner dolphin	0	1
Rough-toothed dolphin	0	2
Bottlenose dolphin	1	864
Cuvier's beaked whale	0	71
Hooded seal	0	0
Harbor seal	0	0
Gray seal	0	0
Totals	**16**	**4,205**

7.0 EFFECTS TO MARINE MAMMAL SPECIES OR STOCKS

The anticipated impact of the activity upon the species or stock.

This section first describes the anticipated impacts to marine mammals from the proposed survey activities (**Section 7.1**) and then provides a summary of the acoustic propagation modeling conducted to estimate the numbers of marine mammals (by species) that may be taken (**Sections 7.2** and **7.3**). **Section 7.4** provides the incidental take numbers.

The complete Acoustic Propagation and Animal Acoustic Exposure Modeling Report is provided in **Appendix A**.

7.1 POTENTIAL EFFECTS OF ACOUSTIC SOUND SOURCES ON MARINE MAMMALS

Underwater noise sources in the proposed survey include active acoustic sound sources such as airguns, as well as continuous (non-pulsed) vessel-related noise. Noise, either natural or anthropogenic, can adversely affect marine life in various ways. Four zones of influence from noise are offered by Richardson et al. (1995) and summarized by Gordon et al. (2004), including (1) zone of audibility – the area within which the sound is both above the animal's hearing threshold and detectable above background noise; (2) zone of responsiveness – the region within which behavioral reactions in response to the sound occur; (3) zone of masking – the area within which the sound may mask biologically significant sounds; and (4) zone of hearing loss, discomfort, or injury – the area within which the sound level is sufficient to cause threshold shifts or hearing damage.

Overall, the potential for impacts of noise from proposed survey-related sound sources on marine mammals may be highly variable and highly dependent on the specific circumstances of a given situation, such as the different types and characteristics of sound sources, and differences in sound propagation depending on the physical environment. Biological factors including the hearing range of marine mammal species present (broad range and most sensitive frequencies), what animals are doing (some may not be bothered when feeding but very bothered when resting), individual hearing loss, animals' previous exposure to noise type, life history stage, reproductive status, health status, etc. all contribute to the impacts of noise on marine mammals. Past studies on the reactions of animals to noise have shown widely varied responses, depending on the individual, age, gender, and the activity in which the animals were engaged (Simmonds et al., 2003).

The range of potential effects from noise, in order of decreasing severity and modified slightly from the four zones initially outlined by Richardson et al. (1995) above, includes death, non-auditory physiological effects, auditory injury–hearing threshold shift, masking, and stress and disturbance, including behavioral response (Richardson et al., 1995; NRC, 2003, 2005; Nowacek et al., 2004; Southall et al., 2007). The following discussion addresses the range of potential effects noted above, with the exception of death and physiological effects, which have been combined.

Chapter 4.2.2.2.1 of the Final Programmatic Environmental Impact Statement (EIS) for the Atlantic Outer Continental Shelf Proposed Geological and Geophysical Activities: Mid-Atlantic and South Atlantic Planning Areas (Atlantic Programmatic EIS) (http://www.boem.gov/Record-of-Decision-Atlantic-G-G/) provides additional information regarding effects the effects of sound on marine mammals (USDOI, BOEM, 2014a).

7.1.1 Death and Non-Auditory Physiological Effects

Direct physical injury, which might result in death, may occur from exposure to high levels of sound or, more commonly, to shock waves associated with sound-producing events such as in-water explosions.

Given the predominant low-frequency sound sources, limited sound production levels (SPLs) and durations, and directionality of higher frequency sound sources associated seismic sound sources, it is not likely that the proposed survey would generate sounds loud enough to cause direct mortality (Det Norske Veritas Energy, 2007).

7.1.2 Auditory Injuries – Hearing Threshold Shift

The minimum sound level an animal can hear at a specific frequency is called the hearing threshold at that frequency. Sounds above a hearing threshold are accommodated until a certain level of sound intensity or duration is reached. Too much exposure at a certain level might cause a shift in the animal's hearing thresholds within a certain frequency range. Following exposure, the magnitude of the hearing impairment, or threshold shift, normally decreases over time following cessation of noise exposure. Threshold shifts can be temporary (TTS) or permanent (PTS) and are defined as follows, as adapted from Southall et al. (2007) and Finneran et al. (2005):

- TTS – the mildest form of hearing impairment; exposure to strong sound results in a non-permanent (reversible) elevation in hearing threshold, making it more difficult to hear sounds; TTS can last from minutes or hours to days; the magnitude of the TTS depends on the level and duration of the noise exposure, among other considerations.
- PTS – permanent elevation in hearing threshold; no data are currently available regarding noise levels that might induce PTS in marine mammals; PTS is attributed to exposure to very high peak pressures and short rise times, or very prolonged or repeated exposures to noise strong enough to elicit TTS.

Several important factors relate to the type and magnitude of hearing loss, including exposure level, frequency content, duration, and temporal pattern of exposure. A range of mechanical effects (e.g., stress or damage to supporting cell structure, fatigue) and metabolic processes (e.g., inner ear hair cell metabolism such as energy production, protein synthesis, and ion transport) within the auditory system underlie both TTS and PTS. The minimum SPL or sound exposure level (SEL) necessary to cause permanent hearing impairment is higher than the level that induces TTS, although there are insufficient data to determine the precise differential.

In June 1997, the High Energy Seismic Survey team (HESS, 1999) convened a panel of experts to assess existing data on marine mammals exposed to seismic pulses and predict exposures at which physical injury could occur. With the limited available data at that time, exposure to airgun pulses with received levels above 180 dB re 1 µPa (root-mean-square [rms] – averaged over the pulse duration) was determined to have a high potential for "serious behavioral, physiological, and hearing effects."

Based on the HESS (1999) panel conclusions, NMFS established a 180-dBrms (received level) threshold criterion for injury from both impulse sound and "continuous" (non-impulsive) sound exposure for cetaceans and a 190-dBrms threshold criterion for pinnipeds (*Federal Register* 68 FR 41314, 2003). Additionally, behavioral response criteria were developed as step-function (all-or-none) thresholds based solely on the rms value of received levels. Thresholds for behavioral response from impulse sounds are 160 dBrms (received level) for all marine mammals, based on behavioral response data for marine mammals exposed to seismic airgun operations (Malme et al., 1983, 1984; Richardson et al., 1986). Thresholds for behavioral response for "continuous" (non-impulsive) sounds have been 120 dBrms (for some but not all sound sources), based on the results of Malme et al. (1984) and Richardson et al. (1990).

Southall et al. (2007) published a paper summarizing noise exposure results (i.e., SELs) and offered a series of new approaches to noise impact determinations for marine mammals. First, the marine mammals were segregated into the functional hearing groups (**Table 5**).

Table 5. Functional marine mammal hearing groups, associated auditory bandwidths, and marine mammal species present in the area of interest. (From: Southall et al., 2007.)

Functional Hearing Group	Estimated Auditory Bandwidth	Marine Mammal Species Present in the Proposed Survey Area
Low-frequency cetaceans	7 Hz to 22 kHz	North Atlantic right whale; blue whale; fin whale; humpback whale; sei whale; Bryde's whale; common minke whale
Mid-frequency cetaceans	150 Hz to 160 kHz	Sperm whale; beaked whales; *Stenella* dolphins; bottlenose dolphin; killer whale; pygmy killer whale; false killer whale; Risso's dolphin; short-finned and long-finned pilot whales; common dolphin; melon-headed whale; Atlantic white-sided dolphin; Fraser's dolphin; rough-toothed dolphin
High-frequency cetaceans	200 Hz to 180 kHz	Pygmy sperm whale; dwarf sperm whale; harbor porpoise
Pinnipeds in water	75 Hz to 75 kHz	Harbor seal; gray seal; hooded seal; and harp seal
Pinnipeds in air	75 Hz to 30 kHz	Harbor seal; gray seal; hooded seal; and harp seal

Hz = hertz; kHz = kilohertz.

Second, sound sources were categorized into functional categories, based on their acoustic and temporal properties. Three sound types were characterized, including single and multiple pulses and non-pulses, with separation of sound types based on understanding of sound exposure, auditory fatigue, and acoustic trauma in terrestrial mammals and applicable damage risk criteria in humans. The review indicated that the lowest received levels of impulsive sounds (e.g., airgun pulses) that might elicit slight auditory injury (TTS) are 198 dB re 1 μPa^2-s in cetaceans and 186 dB re 1 μPa^2-s in pinnipeds. Odontocetes exposed to impulsive sounds developed TTS with exposures as low as approximately 183 dB re 1 μPa^2 s. It should be noted that these received sound levels are expressed in SEL terms. Southall et al. (2007) also concluded that receipt of an instantaneous flat-weighted peak pressure exceeding 230 dB re 1 μPa (peak) for cetaceans or 218 dB re 1 μPa (peak) for pinnipeds might also lead to auditory injury even if the aforementioned cumulative energy-based criterion was not exceeded.

The following determinations regarding TTS and PTS are noteworthy:

- recently acquired data indicate that TTS onset in marine mammals is more closely correlated with the received SEL than with sound pressure (rms) levels and that received sound energy over time should be considered a primary measure of potential impact, not just the single strongest pulse (Southall et al., 2007); and
- TTS values for pinnipeds are not well defined; while there are published data on levels of non-impulse sound (see Kastak et al., 1999), data are not available regarding impulse sound and TTS in pinnipeds. Based on the results for non-impulse sound, the TTS for pinnipeds exposed to impulse sound may be as low as 171 dB re 1 μPa2 s in the more sensitive species such as the harbor seal.

The primary measure of sound used in the proposed new criteria is the received sound energy, not just in the single strongest pulse, but accumulated over time. Received sound energy over a period of time or, in this case, a series of pulsed sounds over a period of time, is the fundamental basis for the SEL metric. Southall et al. (2007) define SEL as "the dB level of the time integral of the squared-instantaneous sound pressure normalized to a 1-s period." The use of an SEL is advantageous because it can account for: 1) cumulative sound exposure; 2) sounds of differing duration; and 3) multiple sound exposures. It also allows comparison between different sound exposures based on total energy (i.e., calculation of a single exposure "equivalent" value; Southall et al., 2007). This approach also assumes no recovery of hearing between repeated exposures. The most appropriate interval over which the received airgun pulse energy should be accumulated is not well defined. However, pending the availability of additional relevant information, recommendations suggest considering noise exposure over 24-hour periods (Southall et al., 2007). The NMFS continues to evaluate the SEL metric for marine mammal injury (i.e., TTS, PTS); however, the current regulatory thresholds remain based on SPLs (i.e., 180/190 dB re 1 μPa [rms] for injury; 160 dB re 1 μPa [rms] for behavioral modification) while the NOAA draft guidance is being evaluated and finalized.

Sound sources associated with the proposed seismic survey program have the potential to produce TTS or PTS in marine mammals present within the range of the operational sound sources, with range to exposure thresholds dependent upon the size of the sound source and other factors; detailed analysis of active acoustic sound source impacts is provided in **Section 7.4.5**. The range of potential effects from noise, in order of decreasing severity and modified slightly from the four zones initially outlined by Richardson et al. (1995), includes death; non-auditory physiological effects; auditory injury/hearing threshold shift; masking; and stress and disturbance, including behavioral response (Richardson et al., 1995; NRC, 2003, 2005; Nowacek et al., 2004; Southall et al., 2007). The more severe potential effects (e.g., temporary or permanent hearing loss) could occur when exposure is close to a sound source (i.e., the magnitude and probability of some effects decrease with increasing distance from a sound source) and when duration of the exposure(s) is longer. Survey protocols and underwater noise mitigation procedures (**Section 11.0**) would be implemented to decrease the potential for any marine mammal to be within the acoustic exclusion zone of an operating airgun array or other sound source, thereby avoiding the highest sound levels. In addition, due to the intermittent nature of airgun sound and since seismic airgun surveys occur in open ocean areas where highly motile cetaceans may move freely to avoid the relatively slow-moving sound source; marine mammal exposures would predominantly be avoided at injurious sound levels and even levels that could negatively affect behavior. Further, the survey would be performed in a systematic fashion along preplotted transects, so it is presumed that exposure to elevated sound would be somewhat localized and temporary in duration; thereby, reducing the potential for impacts..

7.1.3 Masking

Noise can affect hearing and partially or completely reduce an individual's ability to effectively communicate; detect important predator, prey, and/or conspecific signals; and/or detect important environmental features associated with spatial orientation (Clark et al., 2009). Masking is defined as the obscuring of sounds of interest by other, stronger sounds, often at similar frequencies. Spectral, temporal, and spatial overlap between the masking noise and the sender/receiver determines the extent of interference; the greater the spectral and temporal overlap, the greater the potential for masking.

Naturally occurring ambient noise is produced from various sources, including wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal noise resulting from molecular agitation (Richardson et al., 1995). Background noise (natural and anthropogenic) can also include sounds from distant human activities (e.g., shipping), particularly in areas where heavy levels of shipping traffic are located. Ambient noise can produce masking, effectively interfering with the ability of an animal to detect a sound signal that it otherwise would hear. Under normal circumstances, in the absence of high ambient noise levels, an animal would hear a sound signal because it is above its absolute hearing threshold. Natural masking prevents a portion or all of a sound signal from being heard. Further masking of natural sounds can result when human activities produce high levels of background noise. Ambient noise is highly variable on continental shelves (e.g., see Desharnais et al., 1999), effectively creating a high degree of variability in the range at which marine mammals can detect anthropogenic sounds.

Masking is a natural phenomenon to which marine mammals have adapted through various mechanisms (e.g., dominant frequency shift; increasing source levels). However, the production of strong sounds at frequencies that are important to marine mammals necessarily increases the severity and frequency of masking. Toothed whales have the ability to facilitate the detection of sounds in the presence of background noise. There is evidence that some toothed whales (e.g., bottlenose dolphin: Au et al., 1974, Moore and Pawloski, 1990, Romanenko and Kitain, 1992; beluga whale: Au et al., 1985, Lesage et al., 1999; false killer whale: Thomas and Turl, 1990) can shift the dominant frequencies of their echolocation signals from a frequency range containing excessive ambient noise toward frequencies with less noise. Several marine mammal species are also known to increase the source levels of their calls in the presence of elevated sound levels (Dahlheim, 1987; Au, 1993; Lesage et al., 1999; Terhune, 1999). While data exist that demonstrate adaptation among odontocetes to reduce the effects of masking at high frequencies, there are fewer data sources available regarding corresponding mechanisms at moderate or low frequencies, or in other marine mammal groups (i.e., mysticetes). Clark et al. (2009) summarize the potential for acoustic masking on baleen whales from anthropogenic sounds, including shipping. Castellote et al. (2010), studying fin whales in the eastern Atlantic and western Mediterranean, documented the shortening of low-frequency (20-Hz) pulse duration, decreasing bandwidth, and decreasing center and peak frequencies as a result of masking from shipping (and seismic) activity. Directional hearing has been demonstrated at frequencies as low as 0.5 to 2 kHz in several marine mammals, including killer whales (see Richardson et al., 1995). This ability may be useful in reducing masking at these frequencies.

Sound sources used during the proposed seismic survey program have the potential to mask marine mammal communication and monitoring of the environment around them, if an individual is present within the calculated distance from the source that would affect marine mammals, as defined by NOAA's acoustic guidelines, and the hearing sensitivity(ies) of marine mammals present coincide with the frequency of the sound source being used. However, the affect depends largely on an animal's proximity to an active source when it is transmitting. Masking effects could cause a long-term decrease in a marine mammal's efficiency at foraging, navigating, or communicating (International Council for the Exploration of the Sea, 2005). For some types of marine mammals, specifically bottlenose dolphins, beluga whales, and killer whales, empirical evidence confirms that the degree of masking depends strongly on the relative directions at which sound arrives and the characteristics of the masking noise (Penner et al., 1986; Dubrovskiy, 1990; Bain et al., 1993; Bain and Dahlheim, 1994).

Survey protocols and underwater noise mitigation procedures (**Section 11.0**) would be implemented to decrease some of the potential risk for any marine mammal to be within the exclusion zone of an operating airgun array or other sound source, thereby reducing the potential for masking.

7.1.4 Stress, Disturbance, and Behavioral Responses

Stress in marine mammals resulting from noise exposure typically involves the sympathetic nervous system. Stress response in marine mammals is immediate, acute, and characterized by the release of the neurohormones norepinephrine and epinephrine (i.e., catecholamines; U.S. Navy, Office of Naval Research, 2009). Various researchers (e.g., Romano et al., 2004) have summarized available evidence for profound activity during stressors such as stranding or predation (Cowan and Curry, 2008; Mashburn and Atkinson, 2008; Eskesen et al., 2009). Romano et al. (2004) note that no quantitative approach to estimating changes in mortality or fecundity because of stress has been identified and that qualitative effects may include increased susceptibility to disease and early termination of pregnancy.

Disturbance can induce a variety of effects including subtle changes in behavior, more conspicuous dramatic changes in activities, and displacement. Disturbance is one of the main concerns of the potential impacts of manmade noise on marine mammals. There is a very wide range of possible behavioral responses to sound exposure, given that the sound is audible to the particular animal, including, in approximate order of increasing severity but decreasing likelihood, the following:

- none observable – animals can become less sensitive over repeated exposures;
- looking at the sound source or increased alertness;
- minor behavioral responses such as vocal modifications associated with masking;
- cessation of feeding or social interactions;
- temporary avoidance behavior, or displacement (emerging as one of the more common responses);
- modification of group structure or activity state; and/or
- habitat abandonment.

Behavioral reactions of marine mammals to sound are difficult to predict because reactions are dependent on numerous factors, including the species being evaluated; the animal's state of maturity, prior experience and exposure to anthropogenic sounds, current activity patterns, and reproductive state; time of day; and weather state (Wartzok et al., 2004). Severity of responses can vary depending on characteristics of the sound source (e.g., moving or stationary, number and spatial distribution of sound source[s], similarity to sounds produced by predators, and other relevant factors) (Richardson et al., 1995;

NRC, 2005; Southall et al., 2007; Wüirsing et al., 2008; Bejder et al., 2009; Barber et al., 2010; Ellison et al., 2011). If a marine mammal reacts to an underwater sound by changing its behavior or moving to avoid a sound source, the impacts of that change may not be important to the individual, the stock, or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on both individuals and the population could be important.

There is considerable available literature on the effects of noise on marine mammals. Richardson et al. (1995) noted that most small and medium-sized toothed whales exposed to prolonged or repeated underwater sounds are unlikely to be displaced unless the overall received level is at least 140 dB re 1 μPa. While a prediction of behavioral responses resulting from received SPLs is problematic, several study results are available. Limited available data indicate that sperm whales (*Physeter macrocephalus*) are sometimes, though not always, more responsive to anthropogenic noise than other toothed whales.

Bain and Dahlheim (1994) observed behavioral changes in a captive killer whale exposed to 135 dB (in a band below 5 kHz), and Bain (1995) effectively used noise with a received level of around 135 dB (with a predominant frequency at 300 Hz) as a deterrent. Olesiuk et al. (2002) found noise from acoustic harassment devices with a source level of 195 dB excluded harbor porpoises within a radius of 3 km (1.9 km), a distance at which received levels were estimated to drop to approximately 135 dB. Individual harbor porpoises may have been kept farther away, as there were sighting limitations beyond 3 km (1.9 km).

Baleen whales probably have better hearing sensitivities than odontocetes at lower sound frequencies and in several studies have been shown to react at received sound levels of approximately 120 dB re 1 μPa (e.g., 0.5 probability of avoidance by gray whales of a continuous noise source; Malme et al., 1988; also see Southall et al., 2007). Traveling blue and fin whales exposed to seismic noise from airguns have been reported to stop emitting redundant songs (McDonald et al., 1995; Clark and Gagnon, 2004). By contrast, Di Iorio and Clark (2010) found increased production of transient calls during seismic sparker operations, suggesting that blue whales respond to noise interference according to the context and the signal produced. They further postulated that animals engaged in near-term, proximate communication are probably afforded an advantage in acoustic behaviors that maintain the immediate social link; for animals engaged in long-term singing directed to a distant audience, information loss is minor if singing is temporarily interrupted. Di Iorio and Clark (2010) determined that blue whales changed their calling behavior in response to a low-frequency, low output sound source that was previously presumed to have minor environmental impact (Duchesne et al., 2007). The mean sound pressure was relatively low, 131 dB re 1 μPa (peak to peak) (30 to 500 Hz) with a mean SEL of 114 dB re 1 μPa^2 -s (90% energy for signal duration estimate; Madsen, 2005). North Atlantic right whales exhibited changes in diving behavior when exposed to noise below 135 dB (Nowacek et al., 2004).

Acoustic reactions of cetaceans to airgun activity include reduced vocalization rates (e.g., Goold, 1996) but no vocal changes (e.g., Madsen et al., 2002) or cessation of singing (e.g., McDonald et al., 1995). Other short-term vocal adjustments observed across taxa exposed to elevated ambient noise levels include shifting call frequency, increasing call amplitude or duration, and ceasing to call (Nowacek et al., 2007). In baleen whales, North Atlantic right whales exposed to high shipping noise increased call frequency (Parks et al., 2007), and some humpback whales responded to low-frequency active sonar playbacks by increasing song length (Miller et al., 2000; Fristrup et al., 2003). Porpoises avoid pingers with source levels of about 130 dB at distances of from 100 to 1,000 m (328 to 3,280 ft), depending on experience and environmental context (Gearin et al., 1996, 2000; Kraus et al., 1997; Laake et al., 1997, 1998; Barlow and Cameron, 1999; Cameron, 2003; Cox et al., 2001; Bain, 2002). Kastelein et al. (1997, 2001) found behavioral responses at lower levels. Williams et al. (2002a,b, 2009) found killer whales exhibited behavioral changes in the presence of a single vessel producing a received level of approximately 105 to 110 dB re 1 μPa. Toothed whales appear to exhibit a greater variety of reactions to manmade underwater noise than do baleen whales. Toothed whale reactions can vary from approaching vessels (e.g., to bow ride) to strong avoidance.

In summary, sound sources used during seismic airgun surveys have the potential to produce stress, disturbance, and behavioral responses in marine mammals if they are present within the range of the operational array. Survey protocols and underwater noise mitigation procedures (**Section 11.0**) would be implemented to decrease the potential for any marine mammal to be within the exclusion zone of an operating sound source, thereby reducing the potential for behavioral responses and injury (PTS/TTS) in close proximity to the sound source. However, beyond the exclusion zone, some behavioral responses may occur.

7.2 ACOUSTIC MODELING METHODS SUMMARY

This section provides a brief overview of the acoustic propagation modeling; please see **Appendix A** for the complete Acoustic Modeling Report. Two acoustic modeling methods were used to determine the sound propagation and exposure estimates proposed in this IHA. First, the Gundalf model (Hatton, 2008), a state of the art airgun source modeling software package used by industry, was used to calculate the distance to the 180 dB RMS isopleth. In this analysis, the Gundalf model was run first using a single frequency and spherical spreading to predict a distance to the 180 dB isopleth of approximately 100 m (328 ft) at a depth of 10 m (3.28 ft). Then Gundalf was run a second time to predict the received waveform (which includes all frequencies) from the anticipated 4,920 cubic inch array at a range of 500 meters and a depth of 10 meters to confirm the distance of the180 dB isopleth. This prediction is based upon the temporal summation of the signature of each individual airgun at that range (500 m) and depth (10 m).

The second model used to predict the acoustic field generated by the proposed airgun array was the range-dependant acoustic model (RAM) (Collins, 1993). This is a single frequency model that uses the parabolic equation (PE) to predict the acoustic propagation. To use RAM for broadband sources such as airguns, an acoustic field is calculated for each center frequency of the 1/3-octave bands comprising the source waveform, and then the individual 1/3-octave acoustic fields are summed to create the full broadband sound field. The beam (or directivity) pattern for each center frequency is calculated for each azimuth (or bearing) from the array in 10° intervals. The source level is also defined for each 1/3-octave band using outputs from the Gundalf model (Hatton, 2008). The RAM model is run with the geoacoustic ocean bottom model option to account for propagation and attenuation through the sea floor.

Both models provide reliable results, but use different methodologies. The Gundalf model produces a predicted acoustic waveform based on the relative positions of the individual airgun sources and virtual point receiver. This result can be measured directly as if it were a real signal. The Gundalf model results provided source level information that was used in the RAM modeling. The RAM model creates frequency-specific, three-dimensional directivity patterns (sound field) based upon the size and location of each airgun in the array. That directivity beam pattern is applied to the source to create frequency-specific source levels, which are expressed as sound exposure levels (SEL). The propagating sound wave interacts with the sound velocity profile, the surface, and the ocean floor to create a full three-dimensional acoustic field prediction that allows all depths in the water column to be examined to calculate the range to the 180 dB RMS isopleth at all water depths.

These acoustic propagation models predicted sound fields for each source and location combination. These were used to estimate the distance from the source to various regulatory sound threshold levels.

7.2.1 Airgun Array Source Model

The analysis included in this IHA used a combination of methods to evaluate the source characteristics of the airgun. The first step was to input a full description of the airgun into the Gundalf model (Hatton, 2008). The Gundalf model produced a predicted array output waveform or signature, *without* the “surface ghost” or surface reflection. This is the predicted signature in the main beam at infinite range, with the amplitude back calculated to one meter. An airgun array does not transmit sound equally in all directions; it has a directivity pattern. The directivity pattern of the array was calculated using the beamforming module in the CASS-GRAB package, a model used by the US Navy (Weinberg, 2004).

7.2.2 Acoustic Propagation Models

The airgun array was modeled using both Gundalf and the RAM model as described above with the Gundalf model results providing source level information input for the RAM model. RAM is a PE-based model that incorporates a geoacoustic ocean bottom model that supports shear wave propagation (Collins, 1993).

The RAM requires the following multiple input datasets:

- Acoustic parameters of the sources, including their loudness, or source level, spectral and temporal characteristics of the acoustic sources; and

  - 32-gun array with a total volume of 4,920 cubic inches.
  - The predicted waveform (signature) of the airgun array was produced by the Gundalf model. The array signature was analyzed using standard spectral analysis techniques to determine the source level in each 1/3-octave band from 10 to 2,000 Hz. The maximum 1/3 octave Sound Exposure Level was 222 dB re 1 μPa^2-sec at 1 m.

- Information on the physical characteristics of the underwater environment (including the sound velocity profile of the water column, the roughness of the water surface which influences acoustic reflection from the surface, and the reflective properties or geologic composition of the seafloor.

  - *Acoustic Propagation Modeling Locations* – Eighteen modeling locations (**Figure 6**) were selected that span the acoustic conditions of the Spectrum proposed seismic survey (**Appendix A, Table 3**). These locations ranged in water depth from 30 to 4,200 m. These modeling locations are within the same set of seasonal and geographic provinces were used as in the Atlantic Programmatic EIS (USDOI, BOEM, 2014a); however, there are slight differences in the exact modeling locations between this document and the Atlantic Programmatic EIS due to the availability of geoacoustic data. Modeling locations were chosen for this analysis that correspond to measured data from core samples (see Bottom Loss Model below). In addition, the Spectrum survey area does not have the same spatial extent as the AOI utilized in the Atlantic Programmatic EIS, therefore certain acoustic modeling zones were not included in the Spectrum analysis.
  - *Wind Speed* – Surface loss is the loss of acoustic energy resulting from interaction with the water's surface. The RAM propagation model requires an input of wind speed to calculate the amount of energy that will be lost with surface interactions. The mean monthly wind speed for the nearest 1° × 1° grid for each site was extracted from the Remote Sensing Systems global database of wind speed (Remote Sensing Systems, 2012).
  - *Bathymetry* – ETOPO1 is a global relief model of the Earth's surface (Amante and Eakins, 2008). The bathymetry for the modeling locations was extracted from this database: http://www.ngdc.noaa.gov/mgg/global/global.html. This database has a 1° resolution in latitude and longitude.
  - *Bottom Loss Model*: Geoacoustic Model Construction – The RAM model was run with a full geoacoustic bottom condition that supports shear wave propagation. A set of five core samples were selected for analysis to estimate the geoacoustic parameters. These included data from ODP sites 390, 533 and 603, as well as AMCOR sites 6002, 6004 and 6008. The core data supported analysis to a depth of approximately 200 meters. Parameter values for deeper strata were extracted from the Atlantic Programmatic EIS (USDOC, BOEM, 2014a).

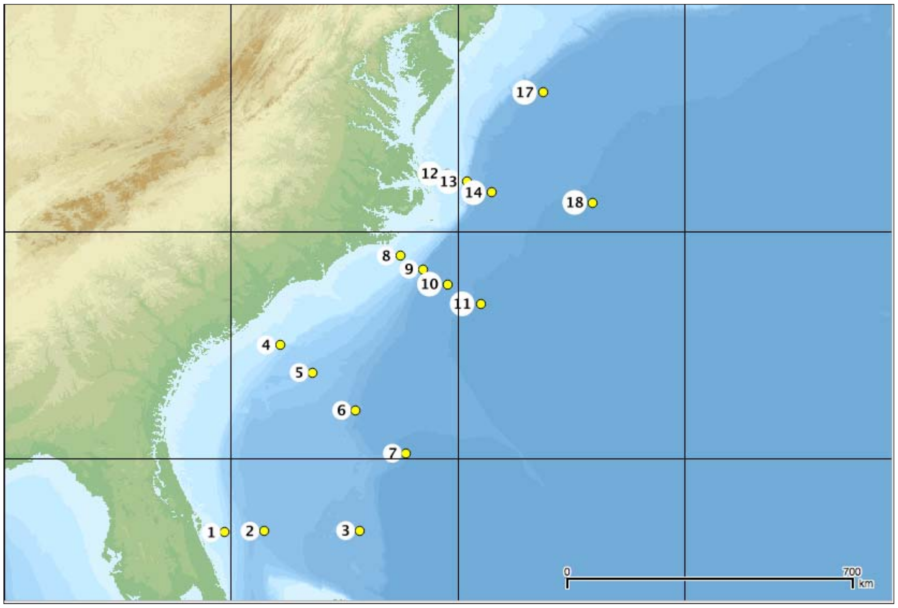

Figure 6. Modeling locations shown with bathymetry.

7.2.3 Acoustic Propagation Modeling Results

In general, sound travelling into deeper water will propagate farther than sound that is traveling into shallower water; however, there is an additive property of energy levels from reflection and refraction in shallow water environments. Since the bathymetry is bearing dependent, RAM was run at various radials to take into account the changing bathymetry. Also, since an airgun array does not transmit sound equally in all directions, the directivity pattern of the array could be incorporated into the propagation modeling. The RAM propagation model was run 36 times at 10° intervals for every modeling location.

The source level (Sound Producing Level [SPL]) calculated from the array signature was expressed as root mean squared (RMS) measure, following the current NMFS regulatory criteria.

The monitoring zone was determined from the RAM propagation model output. For each modeled location, the maximum and 95th percentile distance to the 160 and 180 dB isopleth, at any depth were calculated. The maximum, or 100th percentile, distance is determined by the farther range to the isopleth value, along any bearing, at any depth in the top two kilometers. Applying this value for all bearings is an overestimate of the ensonified area, since the airgun array has horizontal directivity and the bathymetry is bearing dependent. Therefore, using the 95th percentile value integrates across the different bearings from the array and provides a more realistic estimate.

The RAM results are in the form of N x 2-D, which approximates a full 3-D sound field. The model was run for a discrete number of bearings (N=36) to produce a full range and depth–dependent acoustic field. This dataset is the source for animat RL values. For each animal position, the nearest bearing is determined, and the range from the source vessel and the animal's depth is used to find the appropriate RL value from the sound field. These RAM results are also used to determine the range to different isopleths. However, those ranges are only used to determine safety radii. The predicted received sound levels come directly from the detailed N x 2-D sound field.

Based on the calculations using the 95th-percentile values (i.e., 95% of the other values are below, and 5% are above it) from the range-dependent acoustic model (RAM) which determines the maximum sound propagation anywhere in the water column from the array, the 180 –dB zone for this survey ranges from 1,100 m (3,609 ft) to 3,950 m (12,959 ft) with an average 1,844 m (6,050 ft) for all sites (**Table 6**) (**Appendix A**). However, the four shallow sites (< 50 m) have significantly larger radii that skew the average, therefore, the average radii for deep water sites (greater than 50 m) is 1,362 m (4,468 ft) and for the shallow water sites (less than 50 m) is 3,287 m (10,784 ft) (**Table 6**). These radii provide general ranges for the 160 and 180 dB RMS exposure criteria (the existing threshold criteria) based on unweighted soundfield predictions (which does not include any hearing function filter)

Table 6. RAM Modeled distances to 180- and 160-dB RMS isopleths.

Modeling Site	Water Depth (meters)	Maximum Distance to 180-dB RMS Isopleth (meters)	95th Percentile Distance to 180-dB RMS Isopleth (meters)	Maximum Distance to 160-dB RMS Isopleth (meters)	95th Percentile Distance to 160-dB RMS Isopleth (meters)
1	45	4,150	3,900	13,150	12,400
2	820	1,850	1,600	11,450	9,900
3	1,000	2,050	1,650	12,700	9,600
4	40	2,800	2,500	8,450	7,850
5	650	1,850	1,700	12,200	9,350
6	1,500	1,800	1,450	10,950	7,600
7	2,600	1,250	1,100	12,700	6,700
8	30	2,950	2,800	8,100	7,650
9	700	1,950	1,500	13,050	9,150
10	3,300	1,250	1,150	10,150	6,700
11	4,200	1,850	1,400	9,800	7,000
12	30	4,400	3,950	26,550	24,300
13	140	1,200	1,150	14,650	14,750
14	2,400	1,650	1,250	11,550	7,650
17	2,200	1,700	1,300	11,550	8,600
18	4,180	1,150	1,100	9,750	7,200
Average		2,116	**1,844**	12,297	9,775
Average of Sites Greater than 50 m		1,629	**1,362**	11,708	8,683
Average of Sites Less than 50 m		3,575	**3,287**	14,062	13,050

To provide take estimates for the proposed survey, acoustic exposure modeling has been conducted to evaluate potential effects on marine mammals, which is provided as Appendix A of this IHA Application.

7.3 ANIMAL ACOUSTIC EXPOSURE MODELING SUMMARY

This section provides a brief overview of the animal acoustic exposure modeling, please see **Appendix A** for the complete report.

7.3.1 Animal Modeling Methodology

Distribution and Density Estimates

At the time of this analysis, the best available data on marine mammal density estimates for the western Atlantic Ocean were the U.S. Navy's Navy Operating Area (OPAREA) Density Estimates (NODES) database (Department of the Navy, 2007; Duke SERDP Web Portal, 2014 http://seamap.env.duke.edu/search/?app=serdp). These density estimates were based on the NMFS Southeast Fisheries Science Center (SEFSC) shipboard surveys conducted between 1994 and 2006, and were derived using a model-based approach and statistical analysis of the existing survey data using the model DISTANCE (Buckland et al., 2001). The outputs from the NODES database are four seasonal surface density plots for each marine mammal species occurring there. However, since the NODES database does not provide data for the most seaward regions of the proposed survey, specifically beyond 200 nmi from shore since the NMFS data extended only out to 200 nmi from the shore and direct density estimates were not available for the area extending from 200 – 350 nmi from shore area (past the U.S. Exclusive Economic Zone). For those regions, the density estimates from the eastern-most edge where data are known were extrapolated seaward to the spatial extent of the proposed seismic survey. New habitat-based density estimates are anticipated from the NOAA Cetacean Density and Distribution Mapping Working Group (CetMap; cetsound.noaa.gov/cda-index) based on models produced by the Marine Geospatial Ecology Laboratory at Duke University. However, at the time of this analysis, these density estimates have not been peer reviewed and published in a scientific journal.

Density estimates were divided into ten zones to cover the winter and spring seasons within the proposed survey area, based on acoustic propagation conditions (**Figures 7-8**) which vary by season and are presented for each species (**Table 7**). The specific received levels predicted by the AIM model, which includes the animat path and the detailed season-specific sound field, were used to generate the predicted exposure values. The isopleth distances (**Table 6**) are presented for informational purposed only, and play no role in the exposure prediction process.

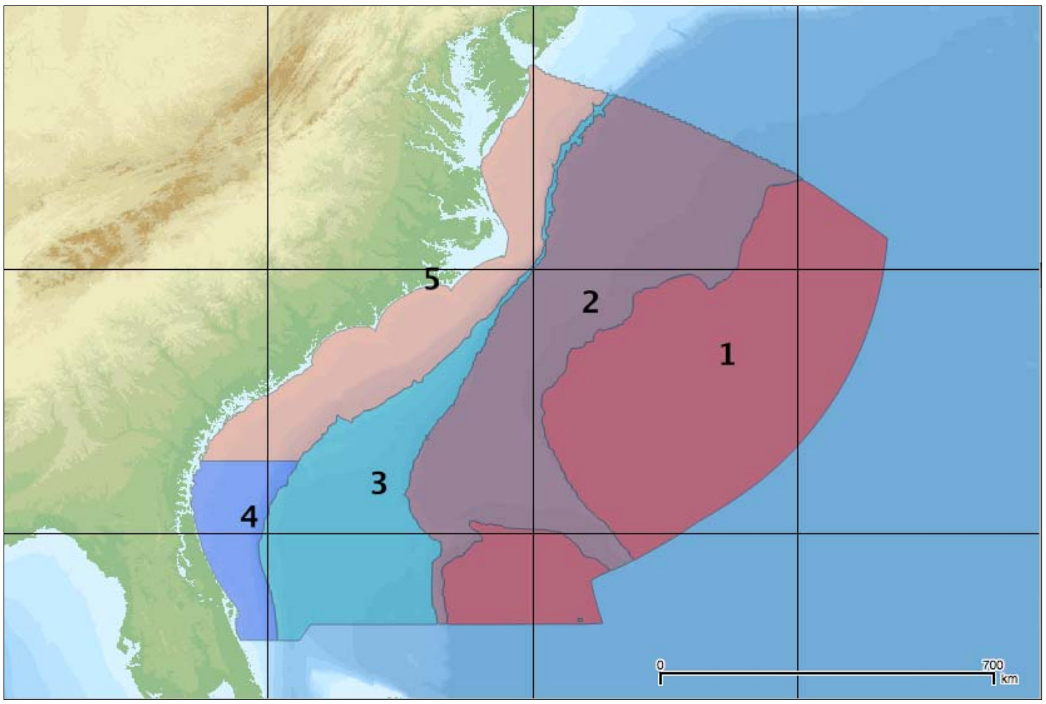

Figure 7. Winter Modeling and Density Zones.

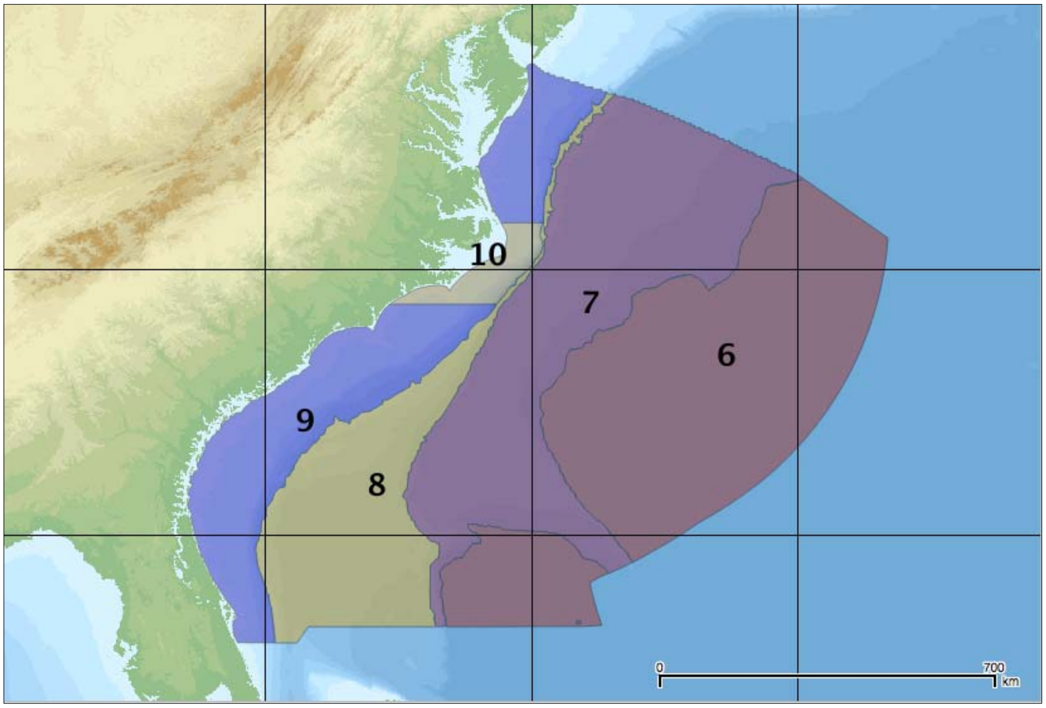

Figure 8. Spring Modeling and Density Zones.

Table 7. Marine mammal density estimates (animals/100 square kilometers) for the 10 modeling and density zones.

	Winter					Spring				
Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mysticetes										
Minke whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Sei whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Bryde’s whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Blue whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fin whale	0.003	0.003	0.015	0.003	0.003	0.003	0.003	0.003	0.015	0.003
North Atlantic right whale	0.000	0.000	0.000	0.111	0.061	0.000	0.000	0.000	0.015	0.015
Humpback whale	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Odontocetes										
Common dolphin	1.593	1.902	5.265	1.593	5.265	1.593	1.902	5.265	5.265	1.593
Pygmy killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Short-finned pilot whale	0.245	2.405	4.383	0.052	0.061	0.073	1.535	4.339	2.557	0.055
Long-finned pilot whale	0.082	0.603	0.556	0.000	0.015	0.023	0.478	0.620	0.364	0.017
Risso's dolphin	0.658	1.313	2.612	0.696	1.934	0.041	1.340	3.215	1.325	0.015
Northern bottlenose whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Pygmy sperm whale	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Dwarf sperm whale	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Atlantic white-sided dolphin	0.050	0.041	0.023	0.000	0.038	0.015	0.015	0.009	0.009	0.015
Fraser’s dolphin	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Sowerby's beaked whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Blainville's beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
Gervais' beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
True's beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
Killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Melon-headed whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Harbor porpoise	0.029	0.023	0.015	0.000	0.023	0.015	0.015	0.009	0.009	0.015
Sperm whale	0.006	0.402	0.530	0.003	0.003	0.006	0.402	0.271	0.003	0.003
False killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Pantropical spotted dolphin	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649
Clymene dolphin	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309
Striped dolphin	0.783	6.733	6.733	0.783	0.967	0.783	6.092	0.783	0.783	0.783
Atlantic spotted dolphin	0.061	6.028	5.446	8.497	9.225	0.061	4.572	2.563	5.879	7.333
Spinner dolphin	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Rough-toothed dolphin	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Bottlenose dolphin	0.521	1.203	8.238	8.238	1.884	0.521	7.557	8.579	0.862	0.862
Cuvier's beaked whale	0.003	0.644	0.646	0.003	0.003	0.003	0.504	0.577	0.003	0.003
Pinnipeds										
Hooded seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Harbor seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Gray seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

Acoustic Integration Model© (AIM)

The Acoustic Integration Model© (AIM) (Frankel et al., 2002) was used to predict the exposure of receivers to the stimulus propagating through space and time. The central component of AIM is the animat movement engine, which moves the stimulus source and animal receivers through four dimensions (time and space) according to user inputs (**Appendix A**). AIM uses external range-dependent stimulus propagation models (e.g., the RAMPE model for this modeling effort) to model the sound propagation from the source.

A separate simulation was created and run for each combination of location, movement pattern and marine mammal species. The specific animal behavioral parameters that were used in this analysis were derived from published literature and are provided in **Appendix A, Section 7**. Marine mammals were simulated by creating animats that were programmed with behavioral values describing dive depth, surfacing and dive durations, swimming speed, and course change. After the animats' movement patterns were defined, the animats were randomly distributed over each simulation area. Each simulation had approximately 3,000 animats representing each species. In most cases, this represents a higher density of animats in the simulation (0.05 animats/km^2) than occurs in the real environment. The modeled animat density value was determined through a sensitivity analysis performed as part of the QA/QC of the AIM modeling results, that examined the stability of the predicted estimate of exposure levels as a function of animat density; the modeled density was determined to accurately capture the full distributional range of probabilities of exposure for the proposed survey. In a later step, potential impacts were normalized back to actual predicted density estimates for each species (**Table 7**). This "over-population" allowed the calculation of smoother distribution tails and in the final analysis all results were normalized back to actual predicted population counts by species. During the AIM modeling, animats were programmed to remain within the simulation area boundaries. This behavior was incorporated to prevent the animats from diffusing out of the simulation, the result of which, if allowed, would be a systematic decrease in animat density over time.

The AIM simulations created a realistic animal movement track for each animat and were based on the best available animal behavioral data (**Appendix A, Section 5.2.3**). It was assumed that, collectively, the ~3,000 animat tracks derived for each simulation (area/species combination) were a reasonable representation of the movements of the animals in the population under consideration. Animat positions along each of these tracks were converted to polar coordinates (range and bearing) from the source. These data, along with the depth of the receiver, were used to extract received level estimates from the acoustic propagation modeling results. Specific to the modeling effort for this IHA, the source levels and therefore subsequently the received levels include the embedded corrections for M-weighting (Southall et al., 2007). For each bearing, distance, and depth from the source when it was operating at that site, the received level values were expressed as SPLs with units of dB re 1μ Pa.

7.3.2 Modeling of the Sound Source Movement

For this assessment, the creation of each modeling simulation began with the creation of a movement pattern for the seismic source vessel representing the survey grid.

AIM simulations consisted of 25 hours of survey track for each modeling site and animal group. The output from these simulations was later scaled to represent the length of the actual survey track.

7.3.3 Modeling Animal Movement

Several movement parameters are used in the model to produce a simulated movement pattern that accurately represents real animal movements, including dive patterns. The horizontal component of the course is handled with the "heading variance" term. It allows the animal to turn up to a certain number of degrees at each movement step. In this case, the animal can change course 20 degrees on the surface, but only 10 degrees underwater. This example is for a narrowly constrained set of variables, appropriate for a migratory animal.

In addition to movement patterns, the animats can be programmed to avoid certain environmental situations. For example, this option can be used to constrain an animal to a particular depth regime. One modification was made for these simulations in the animal's habitat. Normally deep-water species were allowed to move into waters as shallow as 100 m (328 ft).

7.3.4 Mitigation Simulation

The proposed survey effort will include mitigation measures designed to reduce potential acoustic impacts to marine mammals. These include a time-area closure for the North Atlantic right whale (**Section 11.2.1**), maintenance of a minimum separation distance between the proposed survey vessels (**Section 11.3**), and visual monitoring and mitigation efforts (**Sections 11.2.2-11.2.4**). Only visual monitoring and mitigation efforts were considered in the modeling effort. Aversion of marine mammals to avoid sound at injurious levels was not included in the modeling since the use of aversion at the time the modeling was performed, early 2014, was not yet considered accepted practice on the best available science (Southall et al., 2007; Miller et al., 2014; Maggi et al., 2010; Cato et al., 2012)

Visual monitoring and mitigation efforts will be conducted during daylight hours (**Sections 11.0** and **13.0**). Protected Species Observers (PSOs) will monitor the area around the source within the 500 m exclusion zone.

The Record of Decision (ROD) issued by BOEM for the Atlantic Programmatic EIS (USDOC, BOEM, 2014b) specifies that if a marine mammal is detected within the proposed 500 m exclusion zone, then the operation of the airgun array will be suspended for 60 minutes after the last observation of the animal within the exclusion zone. This is done to reduce the acoustic exposure of marine animals and will reduce the number of animals that receive levels that exceed regulatory thresholds. Therefore the effect of visual monitoring and mitigation was included in the modeling effort , using the procedure developed for the National Science Foundation (NSF)-U.S. Geological Survey (USGS) seismic EIS (NSF-USGS, 2011; Appendix B; http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/app-b-amr.pdf).

The dataset outputs of the AIM simulation model contained the received sound level (SEL or SPL), the distance between the source and the animat, and the depth of the animat. The distance value was used to determine if the animat was in the exclusion zone specified for each modeling area. The depth of the animat was used to determine if it was at or near the surface. If both of these conditions were true, then the animat was considered 'available' to be observed.

The monitoring simulation program was then run on all of the data. The movement data were examined at each time step to determine if any of the animats were within the exclusion zone. If so, then a procedure was run to model whether or not the simulated animal would have been detected by a virtual MMO. If an animal is at the surface and within the exclusion zone, it is available for detection (availability bias). However, it may still not be detected because of perception bias (the fact that not all animals that are available for detection are detected by observers). The probability of detection captures perception bias. To determine whether an animal would be detected, a random number was generated and compared to the probability of detection for the species being modeled (*P*(detect)) (NSF-USGS, 2011). If the random number was less than the *P*(detect) value then the animal was considered to have been detected. Conversely, if the random number was greater than the *P*(detect) value, the animal was modeled as undetected. For example, if there was a 75% probability of detection of a given species (*P*(detect) = 0.75), and the random number generator returned 0.5, then the animal would be considered to be detected. If an animat was detected, then the program would simulate the effect of the airgun source being shut down by setting the received sound levels of ALL animats in the run to 0 for the next 60 minutes, as specified in the ROD (USDOC, BOEM, 2014b).

7.4. SEISMIC SURVEY RELATED INCIDENTAL EXPOSURE

Estimates of Level A and Level B exposures were calculated using unweighted 180/190 dB re 1 μPa (Level A) and 160 dB re 1 μPa (Level B) (rms) and using a sound exposure level (SEL) frequency-weighted basis (received energy levels). Separate calculations were made using peak pressure criteria (230 dB re 1 μPa [peak] for cetaceans and 218 dB re 1 μPa [peak] for pinnipeds) as discussed in Southall et al. (2007); however, no exposures to these peak pressure criteria are predicted to occur. For comparative purposes, Level A exposure was also calculated using both the 180/90 dB rms metric and Southall et al., 2007 SEL criteria, the latter of which is most similar to the more recent NOAA draft guidance on underwater acoustic thresholds for onset of PTS (NOAA, 2015). Both are presented in detail in **Appendix A**.

However, since the development and application of the 180 dB re 1 μPa (rms) criteria, additional scientific research has been completed that further clarifies the received levels of underwater sound at which the onset of TTS or PTS occur in marine mammals (Kastak et al., 1999; 2005; Finneran et al., 2002, 2005; Schlundt and Finneran, 2011; Finneran and Jenkins, 2012). These are expressed as sound exposure levels (SEL).

One specific change based on the additional research is the use of an SEL. SEL is advantageous because it can account for: 1) cumulative sound exposure; 2) sounds of differing duration; and 3) multiple sound exposures. It also allows comparison between different sound exposures based on total energy (i.e., calculation of a single exposure “equivalent” value; Southall et al., 2007). However, this approach assumes no recovery of hearing between repeated exposures which may not adequately represent pulsed sound source types such as airguns. Furthermore, the most appropriate interval over which the received airgun pulse energy should be accumulated is not well defined. Pending the availability of additional relevant information, recommendations suggest considering noise exposure over 24-hour periods (Southall et al., 2007). The NMFS continues to evaluate the SEL metric for marine mammal injury (i.e., TTS, PTS); however, the current regulatory thresholds remain based on SPLs (i.e., 180/190 dB re 1 μPa [rms] for injury; 160 dB re 1 μPa [rms] for behavioral modification).

7.4.1 Level A Incidental Exposure Estimates Using Current Regulatory Criteria

In this section, estimates of the MMPA incidental harassment Level A (potential to injure) exposures are presented using current NMFS criteria for cetaceans and pinnipeds (180 dB_{rms} and 190 dB_{rms} received level threshold criterion, respectively) considering mitigation including a 500 m exclusion zone and NARW seasonal closures (**Section 11.2**) and implementing NMFS’ use of the 24-hour reset function for animal exposure estimation procedures. Incidental exposure estimates for proposed airgun seismic surveys for the proposed survey grid are presented in **Table 8** and assumed that 50% of the the survey would occur during in each winter and spring seasons. Estimates for each species are expressed as seasonally adjusted totals and overall (annual) totals. Level A exposure estimates for the proposed survey grid that do not consider mitigation (unmitigated) are provided in **Appendix A, Table 16**.

The potential impacts from the calculated Level A exposures from the survey include the potential to produce TTS or PTS in marine mammals present within the range of the survey operational sound sources, with detailed analysis of active acoustic sound source impacts provided in **Section 7.4.5**. Survey protocols and underwater noise mitigation procedures (**Section 11.0**) would be implemented to decrease the potential for any marine mammal to be within the acoustic exclusion zone of an operating airgun array or other sound source, thereby avoiding the highest sound levels.

Table 8. Predicted 180 dB Level A exposures for the survey grid with mitigation (using 500 m exclusion zone and NARW seasonal closures) (scientific rounding).

	Seasonally Adjusted Exposure Estimates
Species	**Total**
Minke whale	1
Sei whale	1
Bryde's whale	1
Blue whale	1
Fin whale	4
North Atlantic right whale	5
Humpback whale	7
Common dolphin	1,308
Pygmy killer whale	1
Short-finned pilot whale	946
Long-finned pilot whale	156
Risso's dolphin	733
Northern bottlenose whale	1
Pygmy sperm whale	3
Dwarf sperm whale	7
Atlantic white-sided dolphin	7
Fraser's dolphin	1
Sowerby's beaked whale	1
Blainville's beaked whale	29
Gervais' beaked whale	29
True's beaked whale	29
Killer whale	1
Melon-headed whale	1
Harbor porpoise	4
Sperm whale	166
False killer whale	1
Pantropical spotted dolphin	219
Clymene dolphin	104
Striped dolphin	1,014
Atlantic spotted dolphin	1,849
Spinner dolphin	1
Rough-toothed dolphin	5
Bottlenose dolphin	1,833
Cuvier's beaked whale	202
Hooded seal	**0**
Harbor seal	**0**
Gray seal	**0**
Totals	**8,671**

Listed species

Within the proposed survey area, Level A exposure estimates for the project duration are predicted for six listed cetacean species:

- North Atlantic right whale (5 exposures)
- Sei whale (1 exposures),
- Blue whale (1 exposures),
- Fin whale (4 exposures),
- Humpback whale (7 exposures), and
- Sperm whale (166 exposures).

Within the survey area, Level A exposures of sperm whales are substantially higher than for other listed species. However, it must be recognized that an exposure does not necessarily equate to a Level A take because behavioral reactions vary for a number of reasons.

Seasonally adjusted exposure estimates for these species reflect temporal variability in their relative densities within the proposed survey areas. Modeling was done on a seasonal basis because of differences in acoustic propagation conditions. Those seasonal modeled estimates were adjusted with the seasonal density estimates to come up with the final overall exposure estimates.

Non-listed Species

Level A exposures from the proposed survey are predicted for all non-listed and modeled marine mammal species.

Total Level A exposure estimates of non-listed cetacean species for the survey area are less than 30 exposures, except for the following (listed in order by exposure):

- Bottlenose dolphin (1,833 exposures)
- Atlantic spotted dolphin (1,849 exposures)
- Common dolphin (1,308 exposures)
- Striped dolphin (1,014 exposures)
- Short-finned pilot whale (946 exposures)
- Risso's dolphin (733 exposures)
- Pantropical spotted dolphin (219 exposures)
- Cuvier's beaked whale (202 exposures)
- Long-finned pilot whale (156 exposures)
- Clymene dolphin (104 exposures)

7.4.2 Level B Incidental Exposure Estimates Using Current Regulatory Threshold

In this section, estimates of current MMPA incidental harassment Level B (behavioral disturbance) was estimated with the unweighted 160 dB re 1 μPa SPL (RMS) and mitigation including a 500-m exclusion zone and NARW seasonal closures (**Section 11.2**) and implementing NMFS' use of the 24-hour reset function for animal exposure estimation procedures. Incidental exposure estimates for proposed airgun seismic surveys for the proposed Survey grid are presented in **Table 9** and assumed that 50% of the the survey would occur during in each winter and spring seasons. Estimates for each species are expressed as seasonally adjusted totals and overall (annual) totals. Level B exposure estimates for the proposed survey grid that do not consider mitigation are provided in **Appendix A, Table 16**.

Table 9. Predicted Level B seasonally adjusted exposure estimates within the survey grid with mitigation (using 500 m exclusion zone and NARW seasonal closures) (scientific rounding).

	Seasonally Adjusted Exposure Estimates
Species	**Total**
Minke whale	11
Sei whale	11
Bryde's whale	11
Blue whale	12
Fin whale	26
North Atlantic right whale	28
Humpback whale	53
Common dolphin	11,481
Pygmy killer whale	8
Short-finned pilot whale	8,093
Long-finned pilot whale	1,497
Risso's dolphin	5,162
Northern bottlenose whale	7
Pygmy sperm whale	22
Dwarf sperm whale	58
Atlantic white-sided dolphin	75
Fraser's dolphin	9
Sowerby's beaked whale	7
Blainville's beaked whale	200
Gervais' beaked whale	200
True's beaked whale	200
Killer whale	10
Melon-headed whale	8
Harbor porpoise	31
Sperm whale	1,002
False killer whale	8
Pantropical spotted dolphin	2,235
Clymene dolphin	1,063
Striped dolphin	14,248
Atlantic spotted dolphin	18,311
Spinner dolphin	10
Rough-toothed dolphin	44
Bottlenose dolphin	16,934
Cuvier's beaked whale	1,390
Hooded seal	0
Harbor seal	0
Gray seal	0
Totals	**82,465**

Listed species

Within the proposed survey area, total Level B exposure estimates are predicted for six listed cetacean species (listed in order by exposure):

- Sperm whale (1,002 exposures);
- Humpback whales (53 exposures);
- Fin whale (26 exposures);
- North Atlantic right whale (28 exposures);
- Sei whale (11 exposures); and
- Blue whale (11 exposures).

Within the survey area, Level B exposures of sperm whales are substantially higher other listed species.

Nonlisted Species

Level B exposures from the proposed survey are predicted for all non-listed marine mammal species. Total Level B exposure estimates of non-listed cetacean species for the survey area are less than 100 exposures, except for the following (listed in order by exposure):

- Atlantic spotted dolphin (18,311 exposures)
- Striped dolphin (14,248 exposures)
- Bottlenose dolphin (16,934 exposures)
- Common dolphin (11,481 exposures)
- Short-finned pilot whale (8,093 exposures)
- Risso's dolphin (5,162 exposures)
- Pantropical spotted dolphin (2,235 exposures)
- Long-finned pilot whale (1,497 exposures)
- Cuvier's beaked whale (1,390 exposures)
- Clymene dolphin (1,063 exposures)
- Blainville's beaked whale (200 exposures)
- Gervais' beaked whale (200 exposures)
- True's beaked whale (200 exposures)

As in the case of Level A exposures, total Level B exposures of bottlenose dolphins was substantially higher than all other non-listed species

7.4.3 Sound Exposure Level (SEL) and Southall Criteria Exposure Estimates

Appendix A, Section 6 provides a discussion of the injury criteria used in the modeling. Level A exposure estimates for the l survey grid using the SEL metric are presented in **Table 16** of **Appendix A**, the Acoustic Modeling Report and Animal Acoustic Exposure Modeling Report. Species with calculated exposure estimates for the survey area are presented in **Table 10**.

Table 10. Predicted SEL Level A exposures for the survey grid with mitigation.

Species	Level A Exposures
Common dolphin	4
Risso's dolphin	1
Striped dolphin	1
Atlantic spotted dolphin	7
Bottlenose dolphin	1
North Atlantic right whale	1
Humpback whale	1
Totals	**16**

7.4.4 Draft Guidance on Underwater Acoustic Thresholds for onset of PTS

Appendix A, Section 6 provides a discussion regarding the NOAA Draft Guidance. When the distances to the 180- and 160-dB isopleths were re-calculated using the hearing functions specified within the draft guidance on underwater acoustic thresholds (NOAA, 2015), the distances are much smaller than those calculated with the traditional approach (**Appendix A, Tables 18 - 20**). Even if the low-frequency cetacean weighting function is used for all species, which is the most conservative of the three cetacean weighting functions (i.e., it is frequency-weighted for low-frequency hearing specialists, thus allowing the greatest amount of energy at the low frequencies to be considered in exposure estimates), there is a significant reduction in the distances to the 160- and 180-dB isopleths (**Table 11**). These reductions in distance to the 180 dB and 160 dB RMS isopleths (**Table 11**) would result in significant reductions in animal exposures (**Table 12**). The average distance at all water depth to the 180 dB RMS isopleth is 191 m for a 99.1% reduction (with an average for shallow water sites of 450 m), which is within the 500 m exclusion zone; and therefore, there would not be exposures to most marine mammals above the 180 dB threshold with the implementation of mitigation measures. In addition, the distance to the 160 dB isopleth is reduced by an average of 94.9% to 2,128 m on average for all water depths (**Table 11**). These exposure reduction percentages are based on the ratio of the areas calculated with isopleths derived from sound fields created with the NOAA LF weighting function and the unweighted sound field; and therefore, the number of marine mammals available for exposure to sound levels at or above 160 dB are reduced.

- SPL 95th percentile distance to 180-dB RMS isopleth = 1,844 m
- Guidance for onset of PTS 95th percentile distance to 180-dB RMS isopleth = 191 m
- SPL 95th percentile distance to 160-dB RMS isopleth = 9,775 m
- Guidance for onset of PTS 95th percentile distance to 160-dB RMS isopleth = 2,128 m

Table 11. RAM modeled ranges (meters) to 180-dB RMS and 160-dB RMS isopleths using the draft low-frequency weighting function (NOAA, 2015).

Modeling Site	Water Depth (meters)	Maximum distance to 180-dB RMS isopleth (meters)	95th percentile distance to 180-dB RMS isopleth (meters)	Estimated Reduction in radii to 180 dB LF exposures (%)	Maximum distance to 160-dB RMS isopleth (meters)	95th percentile distance to 160-dB RMS isopleth (meters)	Estimated Reduction in radii to 160 dB LF exposures (%)
1	45	750	600	97.6	4,800	4,500	86.4
2	820	150	150	99.1	1,950	1,750	96.9
3	1,000	150	150	99.2	2,050	1,900	96.1
4	40	200	150	99.6	2,450	2,150	92.5
5	650	150	150	99.2	2,100	1,850	96.1
6	1,500	150	100	99.5	1,900	1,600	95.6
7	2,600	150	100	99.2	1,300	1,150	97.1
8	30	500	450	97.4	3,250	3,050	84.1
9	700	150	150	99.0	2,050	1,600	96.9
10	3,300	150	50	99.8	1,150	1,200	96.8
11	4,200	150	50	99.9	1,200	1,150	97.3
12	30	650	600	97.7	7,200	6,850	92.1
13	140	100	100	99.2	1,400	1,300	99.2
14	2,400	150	100	99.4	1,900	1,400	96.7
17	2,200	150	100	99.4	1,900	1,450	97.2
18	4,180	150	50	99.8	1,200	1,150	97.4
Average		**241**	**191**	**99.1%**	**2,363**	**2,128**	**94.9%**
Average of Sites Greater than 50 m		**146**	**104**		**1,675**	**1,458**	
Average of Sites Less than 50 m		**525**	**450**		**4,425**	**4,138**	

If these estimated reductions for the low frequency weighting function (the most conservative of the three cetacean weighting functions) was applied to all Level A (180 dB) and Level B (160 dB) exposures estimates, the resulting exposures would be reduced an average of 99.1% and 94.9%, respectively (**Table 12**).

Table 12. Estimated reductions in exposure estimates after applying average estimated reductions using the low frequency weighting function (Totals with scientific rounding).

Species	180 dB	160 dB
Minke whale	0	1
Sei whale	0	1
Bryde's whale	0	1
Blue whale	0	1
Fin whale	0	1
North Atlantic right whale	0	1
Humpback whale	1	3
Common dolphin	118	585
Pygmy killer whale	0	0
Short-finned pilot whale	85	413
Long-finned pilot whale	14	76
Risso's dolphin	66	263
Northern bottlenose whale	0	0
Pygmy sperm whale	0	1
Dwarf sperm whale	1	3
Atlantic white-sided dolphin	1	4
Fraser's dolphin	0	0
Sowerby's beaked whale	0	0
Blainville's beaked whale	3	10
Gervais' beaked whale	3	10
True's beaked whale	3	10
Killer whale	0	1
Melon-headed whale	0	0
Harbor porpoise	0	2
Sperm whale	15	51
False killer whale	0	0
Pantropical spotted dolphin	20	114
Clymene dolphin	9	54
Striped dolphin	91	727
Atlantic spotted dolphin	166	934
Spinner dolphin	0	1
Rough-toothed dolphin	0	2
Bottlenose dolphin	165	864
Cuvier's beaked whale	18	71
Hooded seal	0	0
Harbor seal	0	0
Gray seal	0	0
Totals	**779**	**4,205**

7.4.5 Conclusions

Modeled marine mammal exposure estimates with historical acoustic criteria (e.g., unweighted 160 dB rms for behavior disruption and 180/190 dB rms for potential to injure) are highly conservative (i.e., use highest estimated animal densities, assume all species are equally sensitive to received sound frequencies and levels) in order to get this upper limit. They are not meant to provide anticipated or actual exposure or take numbers. These marine mammal exposure estimates take into account the time-area closure for the North Atlantic right whale (**Section 11.2.1**) and visual monitoring and mitigation efforts (**Sections 11.2.2-11.2.4**). Aversion was not included in the modeling since at the time the modeling was performed, early 2014; this practice was considered risky and not accepted practice. Therefore, the Level A and Level B exposure estimates are over estimated since some marine mammals have shown some avoidance reactions to airguns (**Section 6**) and would avoid exposure to these sound levels; thus reducing the Level A and Level B exposures. However even with these limitations, modeling is the best available tool to provide a metric to assess the potential effects of seismic surveys on marine mammals and provides an evaluation of how mitigation measures can reduce these effects, but recognizing that mitigation measures cannot be effective 100% of the time. In addition, since there is no guidance regarding the differences between Level A and Level B modeling results (exposures) and actual "takes" and recognizing that an exposure to sound levels above 180 and 160 dB does not necessarily equal a "take" the discussion above has provided a basis for the requested Level A and Level B precautionary takes presented in **Section 6** based on several factors including the new NOAA draft acoustic thresholds for onset of PTS.

Considering the best available science, the changing acoustic guidance and criteria, modeling results using Southall et al. (2007) SEL criteria, and the estimated exposures using the NOAA draft guidance on underwater acoustic thresholds the modeled Level A and Level B exposures presented in **Sections 7.4.1** and **7.4.2** using the SPL historical acoustic criteria (e.g., unweighted 160 dB rms for behavior disruption and 180/190 dB rms for potential to injure) are not equivalent to Level A and Level B take estimates. However, the information provided above that includes all three acoustic guidance and criteria which provides the basis for the precautionary take estimates requested in **Section 6**.

Based on all of the information provided above, it is likely that seismic airgun survey-related noise associated with the proposed activities may impact individuals and groups of marine mammals within the proposed survey area, including listed and nonlisted cetacean species on the continental shelf, shelf edge, and slope. As noted previously, baleen whales are believed to be low-frequency specialists with best hearing sensitivity below 3 kHz (Ketten, 2000). It is assumed that baleen whales, in general, are more susceptible to low-frequency anthropogenic sounds than are odontocetes (Ketten, 2000). However, it is likely that mysticete whale densities within the proposed survey area will be low, as reflected in modeled density and exposure estimates. Smaller odontocetes are most sensitive in the 30-120 kHz range (Au, 1993) and relatively insensitive to low-frequency sounds (Au et al., 1997). Marine mammal species with the highest exposure estimates are the odontocetes (e.g., delphinids), all of which are mid- to high-frequency specialists and are relatively insensitive to low-frequency sounds.

There are significant differences among modeling results for Level A exposures developed using SPL historical acoustic criteria (e.g., unweighted 160 dB rms for behavior disruption and 180/190 dB rms for potential to injure) and SEL potential injury criteria (Southall et al., 2007) metrics. For example, AIM© modeling results using the SEL potential injury criteria (Southall et al. 2007) metric estimate exposure of less than 1 individual for five species (Risso's dolphin, striped dolphin, bottlenose dolphin, North Atlantic right whale, and humpback whale) (**Table 10**) whereas the estimated exposure for the same species using the SPL metric are 733; 1,014; 1,833; 5; and 7, respectively (**Table 8**).

Level A exposure estimates presented in this analysis are meant to be highly conservative upper limits of exposure that consider the role of mitigation as discussed in **Section 7.3.4** in reducing exposure. They are not expected levels of actual take. The potential consequences of Level A harassment would be expected to include injury onset, specifically the onset of PTS. TTS is the mildest form of hearing impairment that can occur during exposure to loud sound. It is not considered to represent physical injury. It is, however, an indicator that physical injury (PTS) is possible if the animal is exposed to higher levels of sound or longer duration of sound. Physical injuries from seismic noise are assumed in this analysis to be limited to PTS. The onset of PTS may result in one or more impacts to an individual or small group. For example, decreased foraging success may be realized for those species that use sound in this capacity (i.e., sperm whales). The PTS also has the potential to decrease the range over which socially significant communication takes place (e.g., communication between competing males, between males and females during mating season, between mothers and offspring).

Using the SPL historic acoustic criteria, modeling of Level B exposure estimates suggest large numbers of individual cetaceans could experience non-injurious impacts from seismic airgun surveys during the project period. For example, total Level B exposures of bottlenose dolphins are estimated at 16,934 exposures. Given the estimated stock size of these populations and survey design (**Section 1.0**), it is likely that individual animals may experience multiple exposures over the course of the survey period. It is presumed that these impacts would largely consist of harassment and would elicit behavioral alterations such as disturbance of activities, avoidance, or temporary displacement from areas of ensonification. However, as shown in **Table 12**, estimated exposures of behavioral disruption using the calculated distances to the 160-dB isopleth (**Table 11**) using the low-frequency cetacean weighting function, the most conservative of the weighting functions, results in significantly reduced estimated total Level B exposures, 4,207 as compared to 82,465, using the SPL historical acoustic criteria.

Behavioral responses of marine mammals to acoustic stimuli vary widely, depending on the species, the context of their activities at the time of ensonification (feeding, migrating, calving, etc.), the properties of the stimuli, and prior exposure of the animals (Wartzok et al., 2004; Nowacek et al., 2007). Species variability in response to anthropogenic noise is also a factor, as distinctions need to be made between taxonomic groups that have widely different hearing and sensitivity frequencies (NRC, 2005). Seismic airgun surveys associated with the proposed activity are planned to occur in open ocean areas where these highly motile cetaceans may move freely to avoid the relatively slow-moving sound source and so would avoid exposure to injurious sound levels and even levels that would negatively affect behavior (Although the AIM model can include aversion behavior of marine mammals from certain received levels, it was not done for this modeling effort since at the time of the modeling, aversion was not an accepted practice). Further, the survey would be performed in a systematic fashion along preplotted transects, so it is presumed that exposure to elevated sound would be somewhat localized and temporary in duration.

The Survey Protocols (**Section 11.0**) specify mitigation measures for marine mammals that are meant to limit Level A exposures and reduce Level B exposures. These include an exclusion zone, ramp-up requirements, visual monitoring by PSOs of the exclusion zone, the utilization of passive acoustic monitoring (PAM), and array shutdown requirements for animals sighted within the 500 m exclusion zone. The proposed project specifies an expanded time-area closure for North Atlantic right whales (airgun surveys would not be conducted within this closure area during this time), and a minimum separation distance between simultaneously operating deep-penetration seismic airgun surveys (which would maintain corridors of lower sound levels (<160 dB) between survey vessels for animals to pass during the survey period (**Section 11.3**). However, even with these mitigation measures in place, the proposed airgun surveys may temporarily displace animals from the survey area; however, these displaced individuals may be in a particular area for specific reasons, such as feeding, community coherence, family bonding, and breeding opportunities. Given each of these effects can mean something different to individual animals, it is impossible to know precisely how many animals will be affected.

In summary, this analysis uses the upper limit of potential exposure provided in the modeled estimates, applies what is known about the likelihood of species in the action area reacting to seismic airgun noise, considers the range of responses from animals that may occur, and applies mitigation to limit the potential for Level A harassment and reduce the potential for Level B harassment. Most impacts would likely be limited to short-term disruption of acoustic habitat and behavioral patterns, abandonment of activities, or displacement of individual marine mammals from discrete areas within the survey area, including both critical and preferred habitats.

7.4.6 Comparative Discussion of Exposure Estimates

Based on the large number of exposure estimates using the current regulatory thresholds provided in **Tables 8** and **9**, it is relevant to note that the current standard procedure for estimating an animal's acoustic exposure uses a "24-hr. reset period." This means that an animal can be "taken" or exposed one time if sound levels exceed the regulatory threshold during that 24-hr. period. At the start of the next 24-hr period, an animal may be "taken" or exposed again, if exposed to a sound level that exceeds the regulatory threshold, resulting in the same animal "taken or exposed" multiple times from the model results and overestimating the number of individuals "taken or exposed".

To illustrate this, consider one hypothetical animal remaining in the vicinity of a noise source for forty hours. The animal is close enough to the sound source so that it continuously receives sound levels above regulatory levels. During that 40-hr. period, that individual animal will have received two exposures, or, two "takes", as per the 24-hour reset rule. For this example, this hypothetical animal is part of a hypothetical population of 100 individuals.

A previously used method to assess the magnitude of a given exposure is to compare the number of animal exposures to the number of individuals in a population (e.g., Wood et al. 2012). In the previous example, two exposures (of a single animal) occurred in a hypothetical total population of 100 individuals. However, the validity of this approach may be limited because it compares two different metrics or units: number of individuals and number of exposures. These are very different units: the number of individuals in a population (typically) changes slowly over years. The number of exposures; however, changes every day or 24-hour period, over the course of the acoustic activity.

This discrepancy of units has minimal effect for activities of short duration. However, as the duration of an activity increases, there is potential for over-estimation regarding exposed or "taken" animals. For example, as in the previous hypothetical illustration above, a year-long activity that "takes" one animal per day. At the end of the year, there are 365 exposures determined by the modeling compared to a hypothetical population of 100 animals, overestimating the number of takes, but reflective of the number of exposures to animals.

The traditional evaluation of magnitude considers the following ratio:

$$\frac{\text{Number of Exposures (animal-days)}}{\text{Number of Individuals}}$$

In the case of a year-long activity with once-a-day exposures to a group of 100 individuals, this would be 365/100, or 3.65% of the population. However, this ratio compares differing metrics (exposures [365]) with differing units (animals [100]). It does not account for a more realistic view of total animal group populations.

A more accurate approach to interpreting these values is to compare the number of realized exposures (modeling results) with the number of potential exposures. In the example above, the model results indicated 365 exposures. However, the number of potential exposures is the number of animals in the population multiplied by the number of days of the seismic activity. In this example that would be 100 animals x 365 days = 36,500 potential animal-days. The metric for the magnitude of the exposure is depicted in this ratio:

$$\frac{\text{Number of Exposures (animal-days)}}{\text{Number of Potential Exposures (potential animal-days)}}$$

Therefore, in this example ratio is 365/36,500 or 1% of the potential exposures that would be realized as the result of the proposed activity. This metric has the logical and mathematical advantage of comparing two values with the same units (animal-days). This approach arguably solves the logical dilemma that is inherent to the traditionally used approach of comparing exposures and numbers of individuals.

In order to provide a comparative basis for the current Level B exposure estimates provided in **Table 10** using the approach described above, **Table 12** includes the species populations available from NODES and provides a comparison of the exposures for the entire survey duration (as determined from the modeling and using the 24-hr reset period) (**Table 10**) to the potential exposures of the species population during the entire survey duration. This comparison uses the same metric across the two methods (animal-days) for those species that have population data available from NODES. When using the comparative basis, **Table 13** provides the percent of the population that could be exposed to levels above the current Level B threshold.

For example, in **Table 10** the modeling results indicate that there will be 11,481 exposures to the common dolphin during the entire survey period of 6 months. **Table 13** indicates that when compared against the average population of common dolphin of 29,416 in each season that could be exposed during the entire survey period results in exposure to 39.2% of the total population that would be exposed to Level B sound levels during the survey. Then when factoring in the total survey duration of 165 days, it results in 0.2% of the total potential exposures to the population of the common dolphin are realized over the survey duration. Another way to compare the metric would be that there are calculated to be 11,481 exposures over a 165-day duration or 69.6 individuals per day exposed or 0.2% of the total population.

Table 13. Comparative Level B number of exposures versus realized exposures within the survey grid with mitigation (using 500 m exclusion zone and NARW seasonal closures) (scientific rounding).

Species	Population Numbers			
	Population		No. of Exposures/No. of Individuals	No. of Realized/ Potential Exposures
	Winter	Spring		
Minke whale[a]	--	--	--	--
Sei whale[a]	--	--	--	--
Bryde's whale[a]	--	--	--	--
Blue whale[a]	--	--	--	--
Fin whale[a]	114	114	21.9%	0.1%
North Atlantic right whale[a]	--	--	--	--
Humpback whale[c]	901	0	9.7%	0.1%
Common dolphin[b]	29,416	29,416	39.2%	0.2%
Pygmy killer whale[a]	--	--	--	--
Short-finned pilot whale[a]	--	--	--	--
Long-finned pilot whale[a]	--	--	--	--
Risso's dolphin[b]	13,835	13,835	37.8%	0.2%
Northern bottlenose whale[a]	--	--	--	--
Pygmy sperm whale[a]	--	--	--	--
Dwarf sperm whale[a]	--	--	--	--
Atlantic white-sided dolphin[a]	--	--	--	--
Fraser's dolphin[a]	--	--	--	--
Sowerby's beaked whale[a]	--	--	--	--
Blainville's beaked whale[a]	--	--	--	--
Gervais' beaked whale[a]	--	--	--	--
True's beaked whale[a]	--	--	--	--
Killer whale[a]	--	--	--	--
Melon-headed whale[a]	--	--	--	--
Harbor porpoise[a]	--	--	--	--
Sperm whale[b]	1,827	2,068	53.1%	0.3%
False killer whale[a]	--	--	--	--
Pantropical spotted dolphin[c]	4,439	4,439	50.5%	0.3%
Clymene dolphin[c]	6,086	6,086	17.5%	0.1%
Striped dolphin[b]	59,882	59,882	23.8%	0.1%
Atlantic spotted dolphin[b]	67,018	67,018	28.1%	0.2%
Spinner dolphin[a]	--	--	--	--
Rough-toothed dolphin[c]	274	274	16.4%	0.1%
Bottlenose dolphin[b]	67,125	67,311	25.4%	0.1%
Cuvier's beaked whale[a]	--	--	--	--
Hooded seal[a]	--	--	--	--
Harbor seal[a]	--	--	--	--
Gray seal[a]	--	--	--	--

[a] = No NODES source data available
[b] = Source is NODES
[c] =Source is NODES Literature

8.0 MINIMIZATION OF ADVERSE EFFECTS TO SUBSISTENCE USES

The anticipated impact of the activity on the availability of the species or stocks of marine mammals for subsistence uses.

There are no traditional subsistence hunting areas in the vicinity of the proposed survey area, and there are no activities related to the proposed seismic survey that may affect the availability of a species or stock of marine mammals for subsistence uses. Consequently, there are no available methods to minimize potentially adverse effects to subsistence uses.

9.0 EFFECTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF HABITAT AND THE LIKELIHOOD OF RESTORATION

The anticipated impact of the activity upon the habitat of the marine mammal populations, and the likelihood of restoration of the affected habitat.

Odontocete whales and dolphins, and pinnipeds that inhabit waters of the proposed survey area feed on fish, cephalopod mollusks, and some may also feed on benthic invertebrates, such as crustaceans and mollusks. Mysticete whales feed primarily on fish and zooplankton. These resouces may be divided into demersal resources (including hard bottom taxa and soft bottom taxa) and pelagic resources (including coastal, epipelagic, and mesopelagic taxa).

Project activities that could potential impact marine mammal habitats include acoustical injury of prey resources. The effects of seismic sound on marine mammal prey, such as squids and fishes, are discussed in detail Chapter 4.2.5 of the Atlantic Programmatic EIS (USDOI, BOEM, 2014a). In seismic airgun surveys, the sound source is constantly moving and intense sounds would rarely be close enough to individuals to inflict physiological or anatomical damage. Species exposed to sound might move away from the sound source, experience short-term auditory injury (threshold shift), experience masking of biologically relevant sounds, increase levels of stress hormones, or may show no obvious effects. Temporary disruption of spawning aggregations or schools of fishes important as prey for marine mammals may occur during a seismic survey. When exposure to sound ends, stress-related behavioral response by fishes would also be expected to end (McCauley et al., 2000a,b). It is not expected that temporary displacement of these resources will lead to permanent habitat alteration or loss, and effects to marine mammals are spatially localized and temporary.

10.0 EFFECTS OF HABITAT LOSS OR MODIFICATION ON MARINE MAMMALS

The anticipated impact of the loss or modification of the habitat on the marine mammal populations involved.

Based on the conclusions of **Section 9** above, no loss or modification of marine mammal habitat is expected and any impacts to prey resources would be minor, with no long-term effects. Therefore, the proposed activity is not expected to have habitat-related effects that could cause significant or long-term consequences for individual marine mammals or their populations.

11.0 METHODS TO REDUCE IMPACT TO SPECIES OR STOCKS

The availability and feasibility (economic and technological) of equipment, methods, and manner of conducting such activity or other means of effecting the least practicable adverse impact upon the affected species or stocks, their habitat, and on their availability for subsistence uses, paying particular attention to rookeries, mating grounds, and areas of similar significance.

11.1 VESSEL STRIKE AVOIDANCE

Vessel strikes are a leading cause of injury and death to large whales, in particular North Atlantic right whales along the east coast (Knowlton and Kraus, 2001). Slow vessel speeds and vigilant monitoring for whales has been shown to reduce whale strikes (USDOC, NMFS, 2005). Vessel strike avoidance measures will be implemented for all survey vessels involved in the proposed survey and will include measures outlined in the Notice to Lessees (NTL) 2012-JOINT-G01 ("Vessel Strike Avoidance and Injured/Dead Protected Species Reporting") (USDOI, BOEM and Bureau of Safety and Environmental Enforcement [BSEE], 2012) which includes NMFS "Vessel Strike Avoidance Measures and Reporting for Mariners," addressing protected species identification, vessel strike avoidance, and injured/dead protected species reporting. Vessel strike avoidance measures will include the following eight key elements:

1. Vessel operators and crews will maintain a vigilant watch for all marine mammals and sea turtles and slow down or stop their vessel, regardless of vessel size, to avoid striking protected species.
   A third-party protected species observer (see Section 2.0) will be placed aboard all survey vessels and will monitor an area around a transiting survey vessel (the vessel strike exclusion zone) according to the parameters stated in items 2 through 8 below, to help ensure it is free of all marine mammals and sea turtles.

2. In accordance with NMFS Compliance Guide for the Right Whale Ship Strike Reduction Rule (50 CFR § 224.105), when safety allows, vessels, regardless of vessel size, shall transit within the 10 kn (18.5 km/h) speed restriction in Dynamic Management Areas (DMA), Mid-Atlantic U.S. SMA from 1 November through 30 April, and critical habitat and Southeast U.S. SMA from 15 November through 15 April.

3. When safety permits, vessel speeds will also be reduced to 10 kn (18.5 km/h) or less when mother/calf pairs, pods, or large assemblages of cetaceans are observed near a transiting vessel.
   A single cetacean at the surface may indicate the presence of submerged animals in the vicinity of the vessel; therefore, precautionary measures must be exercised when an animal is observed.

4. When North Atlantic right whales are sighted at any time during the year, all vessels, regardless of size, will maintain a minimum separation distance of 500 m (1,640 ft). The following avoidance measures must be taken if a vessel comes within 500 m (1,640 ft) of a right whale:

   a) While underway, the vessel operator shall steer a course away from the right whale at 10 kn (18.5 km/h) or less until the minimum separation distance has been established.
   b) If a right whale is spotted in the path of a vessel or within 100 m (328 ft) of a vessel underway, the operator shall reduce speed and shift engines to neutral. The operator shall re-engage engines only after the whale has moved out of the path of the vessel and is more than 100 m (328 ft) away. If the whale is still within 500 m (1,640 ft) of the vessel, the vessel shall select a course away from the whale's course at a speed of 10 kn (18.5 km/h) or less. This procedure shall also be followed if a right whale is spotted while a vessel is stationary. Whenever possible, a vessel should remain parallel to the whale's course while maintaining the 500-m distance as it transits, avoiding abrupt changes in direction until it has left the area.

5. Year-round, when ESA-listed whales other than North Atlantic right whales are sighted, vessels, regardless of size, will maintain .a minimum separation distance of 100 m (328 ft). The lessee and/or operator will ensure that the following avoidance measures are taken if a vessel comes within 100 m (328 ft) of an ESA-listed whale(s) species:

    a) The vessel underway will reduce speed and shift the engine to neutral, and must not engage the engines until the whale has moved outside of the vessel's path and the minimum separation distance has been established.
    b) If a vessel is stationary, the vessel will not engage in engines until the ESA-listed whale(s) has moved out of the vessel's path and beyond 100 m (328 ft).

6. Year-round, survey vessels, will maintain a distance of 50 m (164 ft) or greater from all other marine mammals (cetaceans, pinnipeds, and manatees). If an animal is encountered during transit, a vessel will attempt to remain parallel to the animal's course, avoiding excessive speed or abrupt changes in course.

7. Vessel crews will report sightings of any injured or dead marine mammals or sea turtles to BOEM, BSEE, and NMFS within 24 hours, regardless of whether the injury or death was caused by their vessel.

Survey vessel operators will comply with NMFS marine mammal and sea turtle viewing guidelines for the Greater Atlantic Region (USDOC, NMFS [2011a] for surveys offshore Delaware, Maryland, or Virginia) or the Southeast Region (USDOC, NMFS [2011b] for surveys offshore North Carolina, South Carolina, Georgia, or Florida) or combined guidance if recommended by NMFS. These measures are meant to reduce the potential for vessel harassment or collision with marine mammals or sea turtles, regardless of what activity a vessel is engaged in.

11.2 SEISMIC AIRGUN SURVEY VISUAL MONITORING PROTOCOL WITH REQUIRED USE OF PASSIVE ACOUSTIC MONITORING

The purpose of the Seismic Survey Protocol is to minimize the potential injury to marine mammals and avoid most Level A harassment of marine mammals. The Airgun Survey Protocol described in the following sections specifies mitigation measures for protected species, including an exclusion zone, ramp-up requirements, visual monitoring by PSOs prior to and during seismic airgun surveys, and array shutdown requirements. The protocol specifies the conditions under which airgun arrays can be started and those under which they must be shut down. It also includes the use of passive acoustic monitoring (PAM) to help detect vocalizing marine mammals, as described in **Section 13.2**.

11.2.1 Time-Area Closures

Time-area closures avoid key habitat areas during times that are biologically important for selected species. Adherence to time-area closures will reduce potential impacts from proposed survey activities, such as noise exposure and vessel interactions (vessel strikes and physical presence) to these species. Although most of the proposed survey area is outside of North Atlantic right whale migratory, calving, and nursery grounds, portions of the survey area occur within those right whale-restricted grounds. In those portions, time-area closures will be implemented to avoid vessel strikes and ensonification in the water column on right whales as indicated in **Figure 9**. The take modeling (**Appendix A**) takes into account this closure in the mitigation measures modeled.

No surveying will take place in the time-area closures of the North Atlantic right whale migratory route critical habitat area, within 37 km (20 nmi) from shore (a continuous strip), from 15 November to 15 April, nor within the Mid-Atlantic and Southeast U.S. SMAs from 1 November to 30 April. Additionally, surveying will not be conducted in active DMAs. Surveying conducted outside these critical habitat areas will remain at sufficient distance from the boundaries such that received acoustic levels at the boundaries are no more than Level B harassment levels as determined by modeling (**Appendix B**).

Surveying activities will not occur within the time-area closure for nesting sea turtles offshore Brevard County, Florida, during the sea turtle nesting season (1 May to 31 October) (**Figure 9**) to avoid disturbing the large numbers of loggerhead turtles (and hatchlings) that are likely to be present in nearshore waters of Brevard County during turtle nesting and hatching season. The Brevard County time-area closure would include the portion of Brevard County that is within the proposed survey area and would extend 11 km (5.9 nmi) offshore (**Figure 9**). The southern border of Brevard County is beyond the southern boundary of the project area; as such, the closure also extends radially from the northern county boundary at the shoreline.

In addition, during the coordination with the adjacent coastal states for Coastal Consistency determinations, several states required additional time-area closures described here.

Maryland

- No seismic testing within 125 nmi of Maryland's coast from April 15 – November 15.

South Carolina

- A time area closure for the entire South Carolina coast from April to early September to protect sea turtles.
- No survey activities within the 98 foot (30 m) depth (approximately 40 nmi) of the South Carolina coast.

Georgia

- On the two offshore-to-onshore oriented survey transects that are from 3-30 mi from shore, the portion of these transects that lie between 20 and 30 miles offshore may be surveyed between April 16 and September 15.
- Entire transects, lying between 3 and 30 miles from shore, may be surveyed between September 16 and November 14.
- Airguns will not be discharge within 20 nm of Georgia from April 1 to September 15.
- Airguns will not be discharged within 30 nm of Georgia from November 15 to April 15.

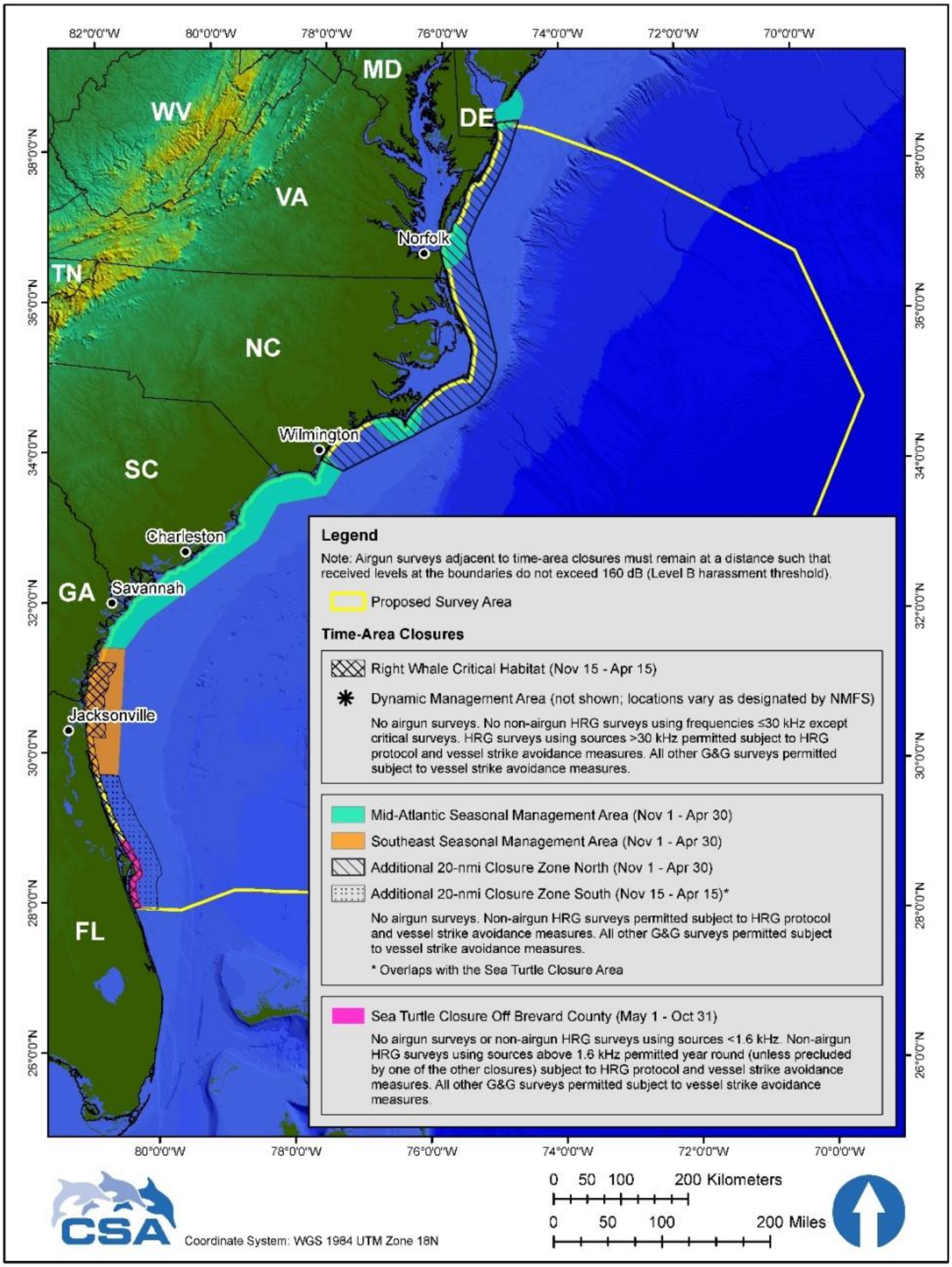

Figure 9. Time-Area Closures.

11.2.2 Exclusion Zone

Visual and PAM protocols are based on noise exposure criteria for physical injuries and behavioral harassment (Level A harassment), and the characteristics of project-specific sound propagation. To minimize the potential for injury and Level A harassment to marine mammals to the maximum extent practical, an exclusion zone will be established centered on the sound source (airguns). A 500 m exclusion zone is proposed to be monitored by PSOs for the pre-ramp up clearance and shutdown if animals were detected within the zone based on the ability to implement effective monitoring in the field.

11.2.3 Ramp-Up Procedures

There is significant uncertainly about the effectiveness of ramp up procedures; however, it is commonly accepted that starting airguns at a lowered power level and gradually building up output is a reasonable approach to providing some level of warning to marine mammals. Ramp-up or "soft start" procedures will be employed such that the gradual increase in airgun array intensity will occur over at least a 20-minute period until maximum source levels are reached. Ramping up of source arrays has been an accepted practice in the seismic industry as a mitigation measure for reducing the risk of acoustic impacts to several marine species. There is limited information regarding its effectiveness; however, for deep-diving whales, the practice may help minimize exposure to the highest energy output of sources since the higher received sound levels are directly beneath the airgun array and ramp-up allows these animals to leave the area prior to full airgun operation. The deep, prolonged diving behavior of this group increases the chance of an individual being located within this high energy output; therefore, the ramp up procedure reduces the chance of this occurrence by not starting at the highest energy output. An animal directly under the source would thus receive a much reduced exposure at the start of the ramp up and theoretically, move away before the exposure reached TTS levels. The intent of ramp-up is to warn marine mammals and sea turtles of impending seismic operations and to allow time for those animals to leave the immediate vicinity. Under normal conditions, animals sensitive to these activities are expected to move out of the area. For all seismic surveys, including airgun testing, use of the ramp-up procedures described below will allow marine mammals and sea turtles to depart the exclusion zone before seismic surveying begins. Measures to conduct ramp-up procedures during all seismic survey operations, including airgun testing, are as follows:

1. Visually monitor the exclusion zone (500 m) and adjacent waters for the absence of all marine mammals and sea turtles for at least 60 minutes before initiating ramp-up procedures. If none are detected, ramp-up procedures may be initiated. Since these protocols require the use of a PAM array, ramp-up and the subsequent start of a seismic survey will be allowed during times of reduced visibility (darkness, fog, rain, etc.) if the minimum source level drops below 160 dB re 1 µPa-m (rms) (see measure 5, below and Section 13.2). Normally, ramp-up during these conditions would not be permitted using only visual observers.

2. Initiate ramp-up procedures by firing a single airgun. The preferred airgun to begin with should be the smallest airgun, in terms of energy output (dB) and volume (in^3).

3. Continue ramp-up by gradually activating additional airguns over a period of at least 20 minutes, but no longer than 40 minutes, until the desired operating level of the airgun array is obtained.

4. Immediately shut down all airguns, if any marine mammal or sea turtle is detected entering the defined exclusion zone (500 m). However, shutdown is not required for dolphins approaching the vessel (or vessel's towed equipment) that indicates a "voluntary approach" on behalf of the dolphin(s). A "voluntary approach" is defined as a clear and purposeful approach toward the vessel by the dolphin(s) with a speed and vector that indicates that the dolphin(s) is approaching the vessels and remains near the vessel or towed equipment. The intent of the dolphin(s) will be subject to the determination of the Protected Species Observer (PSO). If the PSO determines that the dolphin(s) is actively trying to avoid the vessel or the towed equipment, the acoustic sources must be immediately shut down as per his/her instruction. The PSO must record the details of any non-shutdowns in the presence of dolphins, including the distance of the dolphin(s) from the vessel at the first sighting of

the dolphin(s); the dolphin(s) heading; where the dolphin positions itself relative to the vessel; how long the dolphin(s) stay near the vessel, and any identifiable behaviors. After a shutdown, seismic operations may commence with a ramp-up of airguns only when the monitoring zone has been visually inspected for at least 60 minutes to help ensure the absence of all marine mammals and sea turtles.

5. The source level of the airgun array (mitigation airgun) may be reduced using the same shot interval as the seismic survey, to maintain a minimum source level of 160 dB re 1 µPa-m (rms) for the duration of certain activities. By maintaining the minimum source level, the 60-minute visual clearance of the monitoring zone will not be required before ramping back up to full output. Activities that are appropriate for maintaining the minimum source level are: 1) all turns between transect lines, when a survey using the full array is being conducted immediately prior to the turn and will be resumed immediately after the turn; and 2) unscheduled, unavoidable maintenance of the airgun array that requires the interruption of a survey to shut down the array. The survey should be resumed immediately after the repairs are completed. There may be other occasions when this practice is appropriate, but use of the minimum source level to avoid the 60-minute visual clearance of the exclusion zone is only for events that occur during a survey using the full power array. The minimum sound source level is not to be used to allow a later ramp-up after dark or in conditions when ramp-up would not otherwise be allowed.

6. Spectrum's mitigation gun is typically a 40 in^3 gun that is part of the source array charged to 1,500 psi to 2,000 psi, which is fired every 10 to 20 seconds and is used as described above. After the use of the mitigation gun, a soft-start or ramp up with a single source element will be initiated prior to data acquisition.

11.2.4 Protected Species Observer Program

The Protected Species Observer Program is an additional method being employed to reduce impacts to species or stocks and their habitats. The complete description of the PSO Program is provided in **Section 13.0**.

11.3 GEOGRAPHIC SEPARATION OF CONCURRENT SEISMIC SURVEYS

Geographic separation between simultaneous seismic airgun surveys will maintain a minimum of 40-km (25-mile) geographic separation between operating seismic airgun surveys to provide a corridor between vessels where airgun noise is below Level B thresholds and approaching ambient levels such that animals may pass through rather than traveling larger distances to go around the survey vessels for deep water locations.

11.4 STATE CONSISTNECY DETERMINATIONS

Spectrum has coordinated with the adjacent coastal states for Coastal Consistency determinations. A summary of the required additional mitigation measures from those determinations are described below.

Delaware

- Adherence to the agreed modifications to the proposed tracklines as reflected in **Figure 1** and include:

  - Complete removal of all survey lines within the BOEM designated offshore Delaware administrative boundary;
  - Complete removal of all survey grid lines in Delaware's mapped recreational fishing use areas;
  - Proposed survey grid lines shifted to maximize buffer zone around Wilmington and Baltimore offshore canyons; and

- Segment of second northern-most proposed survey grid line to be terminated at nexus of fist intersecting line.

- Notify Delaware Department of Natural Resources and Environmental Control Division of Fish and Wildlife Environment Agency prior to working in Delaware's mapped recreational fishing use areas and again when leaving the vicinity.
- Creation of a Communications Plan to mitigate any potential user conflict including specified elements.

Maryland

- No seismic testing within 125 nmi of Maryland's coast from April 15 – November 15.
- Notification to the State prior to working in offshore waters adjacent to Maryland and again when leaving the vicinity.
- Creation of a Communications Plan with specified elements.
- Modified transect lines as shown in **Figure 1**.

Virginia

- None

North Carolina

- Required pre-survey meeting with Spectrum and representatives of the DMF and DCM to review and discuss precise survey transects and timing to avoid, minimize, and mitigation possible impacts or conflicts to resources.

South Carolina

- A time area closure for the entire South Carolina coast from April to early September to protect sea turtles.
- No survey activities within the 98 foot (30 m) depth (approximately 40 nmi) of the South Carolina coast.
- Modified transect lines as shown in **Figure 1** and include shorten transects that bisected Marine Protected Areas: Edisto, Georgia, Northern South Carolina, and Charleston Deep and the Georgetown Hole Essential Fish Habitat.
- Communicate closely with SCDHEC, SCN, DNR, and the South Atlantic Fisheries Management Council (SAFMC) specialists before and during survey operations.

Georgia

- On the two offshore-to-onshore oriented survey transects that are from 3-30 mi from shore, the portion of these transects that lie between 20 and 30 miles offshore may be surveyed between April 16 and September 15.
- Entire transects, lying between 3 and 30 miles from shore, may be surveyed between September 16 and November 14.
- Airguns will not be discharge within 20 nm of Georgia from April 1 to September 15.
- Airguns will not be discharged within 30 nm of Georgia from November 15 to April 15.
- Notify GaDNR regarding operations of vessels in offshore water adjacent to Georgia.
- Vessels will have functioning automatic identification system (AIS) onboard and operating at all times and vessel names and call signs will be provided to GADNR.

Florida

- None

12.0 POTENTIAL FOR SUBSISTENCE IMPACTS

Where the proposed activity would take place in or near a traditional Arctic subsistence hunting area and/or may affect the availability of a species or stock of marine mammal for Arctic subsistence uses, the applicant must submit either a "plan of cooperation" or information that identifies what measures have been taken and/or will be taken to minimize any adverse effects on the availability of marine mammals for subsistence uses.

There are no traditional subsistence hunting areas in the vicinity of the survey area, as well as no activities related to the proposed survey activities that may affect the availability of a species or stock of marine mammals for subsistence uses.

The suggested means of accomplishing the necessary monitoring and reporting that will result in increased knowledge of the species, the level of taking or impacts on populations of marine mammals that are expected to be present while conducting activities and suggested means of minimizing burdens by coordinating such reporting requirements with other schemes already applicable to persons conducting such activity. Monitoring plans should include a description of the survey techniques that would be used to determine the movement and activity of marine mammals near the activity site(s) including migration and other habitat uses, such as feeding.

13.1 PROTECTED SPECIES OBSERVER PROGRAM

13.1.1 Basic Requirements

PSOs will be on board seismic survey vessels to visually monitor the monitoring zone around the sound source to help ensure it is free of all marine mammals and sea turtles during operation of the survey equipment. All PSOs will be third-party observers and will have completed a PSO training program, described in **Section 13.1.2**. The following guidelines will be followed by PSOs on seismic survey vessels:

1. At least two PSOs will be on duty at all times during daylight hours (dawn to dusk) when seismic operations are being conducted, unless conditions (fog, rain, darkness) make sea surface observations impossible. If conditions deteriorate during daylight hours such that the sea surface observations are halted, visual observations will resume as soon as conditions permit.

2. Other than brief alerts to bridge personnel of maritime hazards, no additional duties will be assigned to PSOs during their watch.

3. No PSO will be allowed more than four consecutive hours on watch as a visual observer.

4. A break of at least 2 hours will occur between 4-hour watches, and no other duties will be assigned during this period.

5. A PSO's combined watch schedule will not exceed 12 hours during a 24-hour period.

13.1.2 Training

All PSOs will have completed a PSO training program. The training program, will be in accordance with the recommendations described in NOAA Fisheries Service 2012 National Standards for a Protected Species Observer and Data Management Program: A Model for Seismic Surveys (Baker et al., 2013). All training programs offering to fulfill the observer training requirement must: 1) furnish to BOEM and NMFS a course information packet that includes the name and qualifications (i.e., experience, training completed, or educational background) of the instructor(s), the course outline or syllabus, and course reference material; 2) furnish each trainee with a document stating successful completion of the course; and 3) provide BOEM and NMFS with names, affiliations, and dates of course completion of trainees.

The training course must include the following elements:

I. Brief overview of the MMPA and the ESA as they relate to seismic acquisition and protection of marine mammals and sea turtles in the Atlantic Ocean.
II. Brief overview of seismic acquisition operations.
III. Overview of seismic mitigation measures and the PSO program.
IV. Discussion of the role and responsibilities of the PSO, including
    a) Legal requirements (why you are here and what you do);

b) Professional behavior (code of conduct);
c) Integrity;
d) Authority of PSO to call for shutdown of seismic acquisition operations;
e) Assigned duties;
   1) What can be asked of the observer;
   2) What cannot be asked of the observer; and
f) Reporting of violations and coercion;

V. Identification of Atlantic marine mammals and sea turtles.
VI. Cues and search methods for locating marine mammals and sea turtles.
VII. Data collection and reporting requirements:
   a) Forms and reports to BOEM and NMFS via email on the first and fifteenth of each month; and
   b) Marine mammal or sea turtle in exclusion zone/shutdown report within 24 hours.

Basic training criteria have been established and must be adhered to by any entity that offers observer training. BOEM will not sanction particular trainers or training programs.

All seismic survey vessels will comply with separate guidance for vessel strike avoidance issued by BOEM and BSEE. Visual observers monitoring solely for vessel strike avoidance (e.g., during transit or other times when airguns are not operating) can be crew members, trained third-party observers, or a combination of both. They do not have specific training requirements, nor will they need to be approved by BOEM or BSEE.

13.1.3 Visual Monitoring Methods

The PSOs on duty will look for marine mammals and sea turtles using the naked eye, and big-eye, or hand-held binoculars provided by the seismic vessel operator. The observers will stand watch in a suitable location that will not interfere with navigation or operation of the vessel and that affords the observers an optimal view of the sea surface. The observers will provide 360-degree coverage surrounding the seismic vessel and adjust their positions appropriately to help ensure adequate coverage of the entire area. These observations will be consistent, diligent, and free of distractions for the duration of the watch.

Visual monitoring will begin no less than 60 minutes prior to the beginning of ramp-up and continue until seismic operations cease or sighting conditions do not allow observation of the sea surface (e.g., fog, rain, darkness). If any marine mammal or sea turtle is observed, the observer will note and monitor the position (including latitude/longitude of the vessel and relative bearing and estimated distance to the animal) until the animal dives or moves out of visual range of the observer. Observations will continue to monitor for additional animals that may surface in the area, as often there are numerous animals that may surface at varying time intervals. At any time a marine mammal or sea turtle is observed within the exclusion zone, whether due to the animal's movement, the vessel's movement, or because the animal surfaced inside the exclusion zone, the observer will call for the immediate shutdown of the seismic operation, including airgun firing (the vessel may continue on its course, but all airgun discharges must cease). Shutdown would not be required for dolphins approaching the vessel (or vessel's towed equipment) that indicates a "voluntary approach" on behalf of the dolphin. A "voluntary approach" is defined as a clear and purposeful approach toward the vessel by the dolphin(s) with a speed and vector that indicates that the dolphin(s) is approaching the vessel and remains near the vessel or towed equipment. The vessel operator must comply immediately with such a call by an on-watch visual observer. Any disagreement or discussion should occur only after shutdown. After a shutdown, when no marine mammals or sea turtles are sighted for at least a 60-minute period, ramp-up of the source array may begin. Ramp-up cannot begin unless conditions allow the sea surface to be visually inspected for marine mammals and sea turtles for 60 minutes prior to commencement of ramp-up (unless the method described in **Section 13.2** is used). Thus, ramp-up cannot begin after dark or in conditions that prohibit visual inspection of (e.g., fog or heavy rain) the monitoring zone. Any shutdown due to a marine mammal or sea turtle sighting within the exclusion zone must be followed by a 60-minute all-clear period and then a standard, full ramp-up. Any shutdown for other reasons, including, but not limited to, mechanical or electronic failure, resulting in the cessation of the sound source for a period greater than

20 minutes, must also be followed by full ramp-up procedures. In recognition of occasional, short periods of the cessation of airgun firing for a variety of reasons, periods of airgun silence not exceeding 20 minutes in duration will not require ramp-up for the resumption of seismic operations if: 1) visual surveys are continued diligently throughout the silent period (requiring daylight and reasonable sighting conditions); and 2) no marine mammals or sea turtles are observed in the monitoring zone. If marine mammals or sea turtles are observed in the monitoring zone during the short silent period, resumption of seismic survey operations must be preceded by ramp-up.

13.1.4 Reporting

The importance of accurate and complete reporting of the results of the mitigation measures cannot be overstated. Only through diligent and careful reporting can BOEM, and subsequently the NMFS, determine the need for and effectiveness of mitigation measures. Information on observer effort and seismic operations is as important as animal sighting and behavior data. In order to accommodate various vessels' bridge practices and preferences, vessel operators and observers may design data reporting forms in whatever format they deem convenient and appropriate. Alternatively, observers or vessel operators may adopt the United Kingdom's Joint Nature Conservation Committee forms (available at their website, www.jncc.gov.uk). At a minimum, the following items should be recorded and included in reports to BOEM:

Observer Effort Report: BOEM requires the submission of observer effort reports to BSEE on the first and fifteenth of each month for each day seismic acquisition operations are conducted. These reports will include the following:

1. Vessel name;
2. Observers' names and affiliations;
3. Survey type (e.g., site, 3D, 4D);
4. BOEM permit number;
5. Date;
6. Time and latitude/longitude when daily visual survey began;
7. Time and latitude/longitude when daily visual survey ended; and
8. Average environmental conditions while on each visual survey rotation and session as well as when any conditions change during the rotation, each session, including:
    a) Wind speed and direction;
    b) Sea state (glassy, slight, choppy, rough, or Beaufort scale);
    c) Swell (low, medium, high, or swell height in meters); and
    d) Overall visibility (poor, moderate, good).

Survey Report: BOEM requires the submission of survey reports to BSEE on the first and fifteenth of the month for each day seismic acquisition operations are conducted and airguns are discharged. These reports will include the following:

1. Vessel name;
2. Survey type (e.g., site, 3D, 4D);
3. BOEM permit number (for "off-lease seismic surveys") or OCS lease number (for "on-lease seismic surveys"), if applicable;

4. Date;
5. Time pre-ramp-up survey begins;
6. Observations of marine mammals and sea turtles seen during pre-ramp-up surveys;
7. Time ramp-up begins;
8. Observations of marine mammals and sea turtles seen during ramp-up;
9. Time sound source (airguns or HRG equipment) is operating at the desired intensity;
10. Observations of marine mammals and sea turtles seen during surveys;
11. If marine mammals or sea turtles were seen, was any action taken (i.e., survey delayed, guns shut down)?;
12. Reason that marine mammals and sea turtles might not have been observed (e.g., swell, glare, fog); and
13. Time sound source (airgun array or HRG equipment) stops firing.

Sighting Report: BOEM requires the submission of reports to BSEE for marine mammals and sea turtles sighted during seismic and HRG surveys on the first and fifteenth of each month, except as indicated below. These reports are in addition to any reports required as a condition of the geophysical permit and must include the following:

1. Vessel name;
2. Survey type (e.g., site, 3D, 4D);
3. BOEM permit number (for "off-lease seismic surveys") or OCS lease number (for "on-lease seismic surveys");
4. Date;
5. Time;
6. Watch status (Were you on watch or was this sighting made opportunistically by you or someone else?);
7. Observer or person who made the sighting;
8. Latitude/longitude of vessel;
9. Bearing of vessel; (true compass direction);
10. Bearing (true compass direction) and estimated range to animal(s) at first sighting;
11. Water depth (meters);
12. Species (or identification to lowest possible taxonomic level);
13. Certainty of identification (sure, most likely, best guess);

14. Total number of animals;

15. Number of juveniles;

16. Description (as many distinguishing features as possible of each individual seen, including length, shape, color and pattern, scars or marks, shape and size of dorsal fin, shape of head, and blow characteristics);

17. Direction of animal's travel – compass direction;

18. Direction of animal's travel – related to the vessel (drawing preferably);

19. Behavior (as explicit and detailed as possible; note any observed changes in behavior);

20. Activity of vessel;

21. Airguns firing? (yes or no); and

22. Closest distance (meters) to animals from center of airgun or airgun array (whether firing or not).

Note: If this sighting was of a marine mammal or sea turtle within the exclusion zone that resulted in a shutdown of the airguns, include in the sighting report the observed behavior of the animal(s) before shutdown, the observed behavior following shutdown (specifically noting any change in behavior), and the length of time between shutdown and subsequent ramp-up to resume the seismic survey (note if seismic survey was not resumed as soon as possible following shutdown). Send this report to BOEM within 24 hours of the shutdown. These sightings should also be included in the first regular semi-monthly report following the incident.

Additional information, important points, and comments are encouraged. All reports will be submitted to BOEM on the first and fifteenth of each month (with one exception noted above). Forms should be scanned (or data typed) and sent via email to BOEM.

Please note that these marine mammal and sea turtle reports are in addition to any reports required as a condition of the geophysical permit.

13.2 PASSIVE ACOUSTIC MONITORING

Whales, dolphins, and porpoises are very vocal marine mammals; periods of silence are usually short and most often occur when these animals are at the surface and may be detected using visual observers. However, marine mammals are at the greatest risk of potential injury from seismic airguns when they are submerged and under the airgun array. PAM has been shown to be very effective at detecting submerged and diving sperm whales, and some other marine mammal species, when they are not detectable by visual observation. The use of PAM is required during all surveying activities as part of the Seismic Airgun Survey Protocol. Inclusion of PAM does **not** relieve an operator of any of the mitigations (including visual observations) in this protocol, **with the following exception**: monitoring for marine mammals with a passive acoustic array by an observer proficient in its use will allow ramp-up and the subsequent start of a seismic survey during times of reduced visibility (darkness, fog, rain, etc.) when such ramp-up otherwise would not be permitted using only visual observers. An assessment of PAM must be included of the usefulness, effectiveness, and problems encountered with the use of that method of marine mammal detection in the reports described in this protocol. A description of the PAM system, the software used, and the monitoring plan must also be reported to BOEM at the beginning of its use.

13.3 BENEFITS OF PROPOSED MONITORING AND REPORTING

Monitoring and reporting protocols described in **Sections 13.1** and **13.2** will provide additional knowledge of marine species, and potentially reduce take of marine mammals from project-related activities. Trained and qualified shipboard PSOs can provide professional and unbiased visual and acoustic observations of protected species. Vigilant watches and acoustic surveys conducted by PSOs will support the protection of marine mammals and sea turtles. The pre-watch period is critical in minimizing the risk, and subsequently the take, of these protected species. Although the vessel is moving during the pre-watch period and therefore does not allow the true clearance of a finite area of water, PSOs will be able to document species seen ahead of the vessel and be alerted to potential species at risk prior to the start of airguns. As a precautionary approach, during ramp-up, airguns will be started at a lower power output, thus reducing the potential for immediate and unprepared exposure to maximum sound pressure levels.

Standardized data collection of observations assists agencies in evaluation of current regulations and the assessment of applicable mitigation measures and ensures full compliance by the operator using legally and scientifically defensible standards. Standardization of data collection also allows comparable data analysis concerning species distributions and activities (behavior). Comprehensive marine species population surveys are costly, and often can only be done within a short time frame. While mitigation monitoring surveys will not replace thorough behavioral studies, they do provide direct *in situ* information regarding species and the surveys.

PAM surveys during seismic acquisition provide a queryable data record of vocalizing marine mammals, as well as sound level measurements for compliance and adaptive management. Much of the modeling component of the mitigation strategies employed are based on few measurements of active surveys; the knowledge gained from the PAM data in relation to the variable bathymetric and environmental conditions will provide valuable insight to the effectiveness of specific mitigation regimes.

14.0 RESEARCH RECOMMENDATIONS

Suggested means of learning of, encouraging, and coordinating research opportunities, plans, and activities relating to reducing such incidental taking and evaluating its effects.

Spectrum will coordinate the planned marine mammal monitoring program associated with the seismic survey with other parties that may have interest in the area and/or be conducting marine mammal studies in the same region during the proposed seismic survey. Spectrum is prepared to share protected species information obtained during the survey program with a variety of groups who may find the data useful in their research. In addition, Spectrum will coordinate with applicable U.S. agencies (e.g., NMFS), and will comply with their requirements.

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APPENDIX A: ACOUSTIC PROPAGATION AND ANIMAL ACOUSTIC EXPOSURE MODELING REPORT

Spectrum Geo Acoustic Propagation and Animal Acoustic Exposure Modeling Report

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1 Introduction

Spectrum Geo is proposing to use an airgun array to explore the ocean floor off the east coast of the United States, roughly from the Florida-Georgia border to Delaware. The proposed activity consists of a regional survey (**Figure 1**).

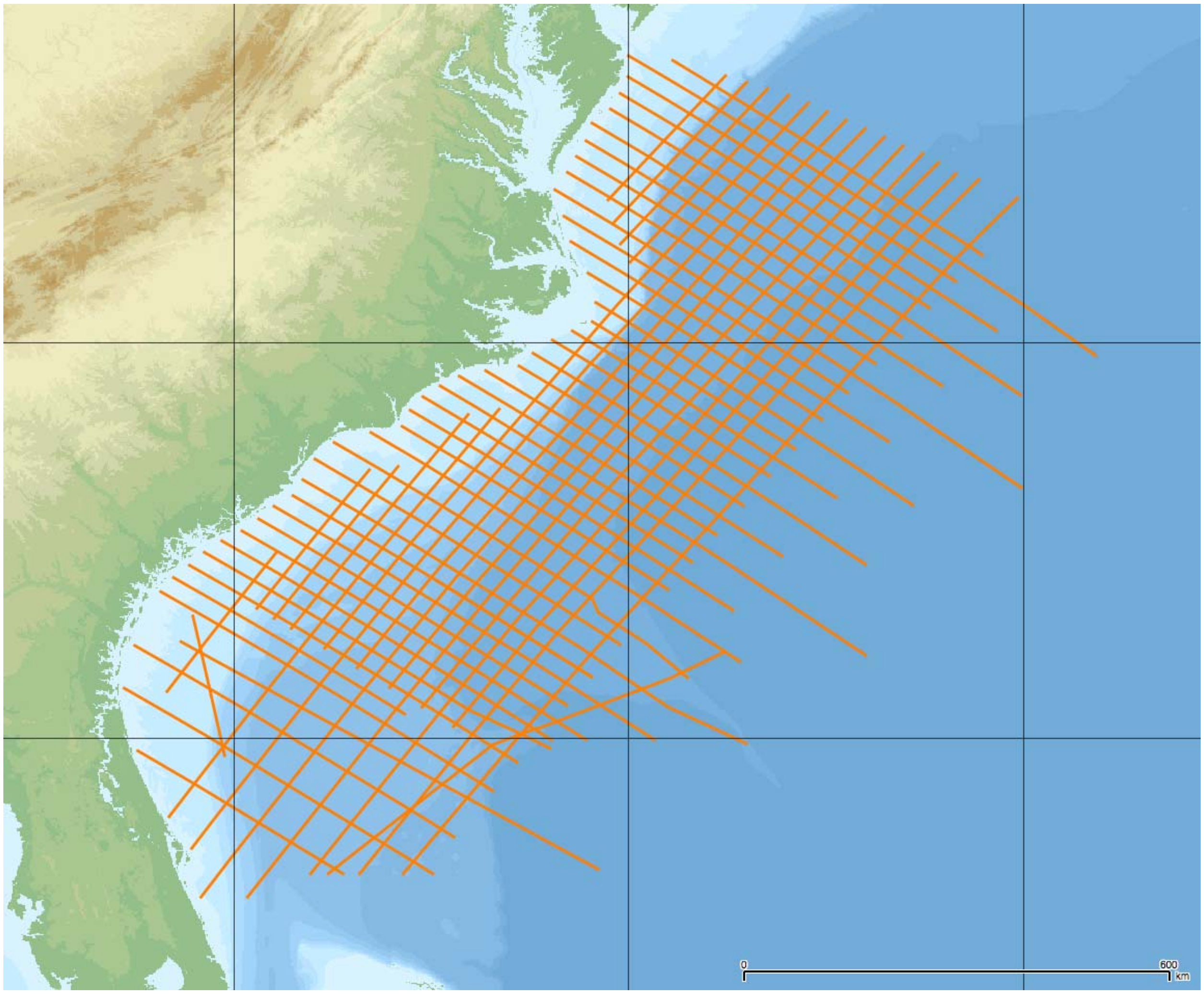

Figure 1. Proposed survey tracklines for the regional study.

This report predicts the levels of sound that would be produced by the proposed seismic survey and determines the exposure of animals to those sound levels. The Acoustic Integration Model (AIM©) simulates the proposed seismic survey and marine mammals to estimate the potential acoustic exposure they may experience. This process involves the integration of a number of variables including 1) the sound source characteristics, 2) the use of acoustic propagation models, 3) environmental inputs needed for the acoustic propagation models, and 4) distribution and movement of marine mammals that are expected to occur in the region, as well as 5) the criteria used to estimate the potential effects of the proposed seismic survey. The output of this integration is the estimated number of animals that might be exposed, which are interpreted to determine potential takes under the Marine Mammal Protection (MMPA) at incidental harassment Level A (injury) or Level B (behavioral disruption).

2 Sound Source Characteristics

The acoustic parameters of the sources must be properly characterized, including their source level and the spectral and temporal characteristics of the anticipated transmissions. For an airgun array source, the geometry and volume of the individual airguns determine its source level and spectral characteristics. Spectrum Geo, Inc. intends to use a 32-gun array with a total volume of 4,920 cubic inches. The array has dimensions of 40 m wide (20 m on each side of the vessel) by 30 m long and is composed of guns ranging in size from 250 to 50 cubic inches (**Table 1**, **Figure 2**). The geometry and volumes were input into the GUNDALF model (Hatton, 2008) to calculate the source level (**Table 2**) and predict the array waveform or signature (left panel **Figure 3**). GUNDALF computes the RMS source level with surface interaction (a "ghost" source), which was accounted for by reducing the GUNDALF-provided RMS source level by 6 dB. This allows the acoustic propagation model to calculate surface reflections as they are predicted to occur, rather than incorporating it into the source level. The array signature was analyzed using standard spectral analysis techniques to determine the source level in each 1/3-octave frequency band from 10 to 2,000 Hz. The maximum 1/3-octave band Sound Exposure Level (SEL) was 222 dB re 1 μPa^2-sec at 1 m (right panel **Figure 3**).

Table 1. Airgun Array Characteristics

Gun	Pressure (psi)	Volume (in^3)	x (m.)	y (m.)	z (m.)
1	2000	250	0	-15.5	10
2	2000	250	0	-14.5	10
3	2000	145	3.8	-15.45	10
4	2000	145	3.8	-14.55	10
5	2000	180	7.4	-15	10
6	2000	120	11	-15	10
7	2000	90	14.1	-15	10
8	2000	50	17.1	-15	10
9	2000	250	0	-5.5	10
10	2000	250	0	-4.5	10
11	2000	145	3.8	-5.45	10
12	2000	145	3.8	-4.55	10
13	2000	180	7.4	-5	10
14	2000	120	11	-5	10
15	2000	90	14.1	-5	10
16	2000	50	17.1	-5	10
17	2000	250	0	4.5	10
18	2000	250	0	5.5	10
19	2000	145	3.8	4.55	10
20	2000	145	3.8	5.45	10
21	2000	180	7.4	5	10
22	2000	120	11	5	10
23	2000	90	14.1	5	10
24	2000	50	17.1	5	10
25	2000	250	0	14.5	10

26	2000	250	0	15.5	10
27	2000	145	3.8	14.55	10
28	2000	145	3.8	15.45	10
29	2000	180	7.4	15	10
30	2000	120	11	15	10
31	2000	90	14.1	15	10
32	2000	50	17.1	15	10

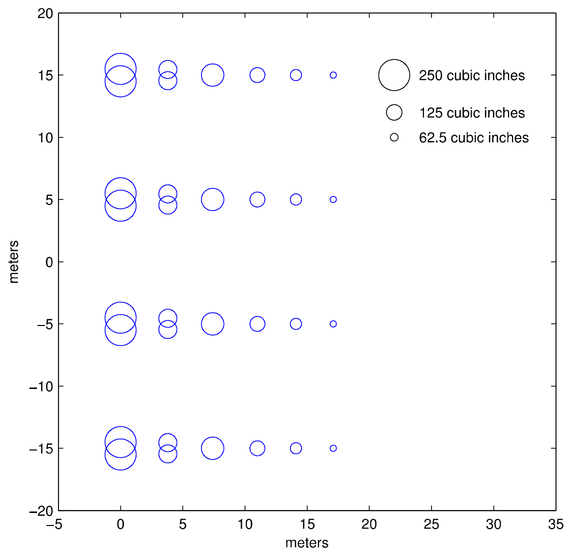

Figure 2. Airgun Array Geometry. Airgun volumes range from 250 to 50 cubic inches. Blue circles represent the location and size of the airguns. Black circles on the right show the size scaling.

Table 2. Airgun array characteristics, with a source depth of 10 m (as reported by GUNDALF with surface interactions)

Array parameter: (0-50,000) Hz	**Array value**
Number of guns	32
Total volume in cu.in (liters).	4920.0 (80.6 liters)
Peak to peak sound pressure level	~ 272 dB re 1 μPa. at 1m.
Zero to peak sound pressure level	266 dB re 1 μPa. at 1m.
RMS Sound pressure level	243 dB re 1 μPa. at 1m.
Maximum spectral value (dB): 10.0 - 50.0 Hz	219
Average spectral value (dB): 10.0 - 50.0 Hz	216

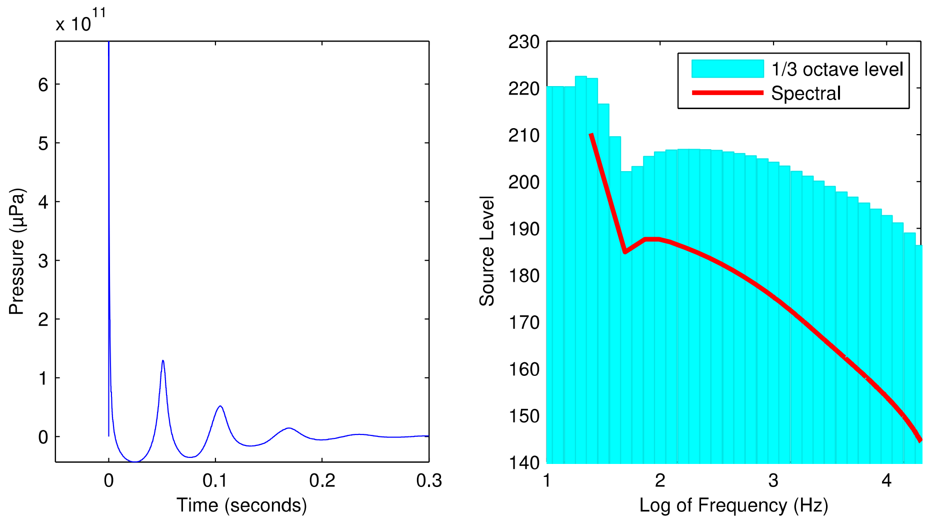

Figure 3. GUNDALF signature waveform and spectral representations. Note that the waveform does not include the surface interaction.

An airgun array does not transmit sound equally in all directions; it has a directivity pattern. The directivity pattern of the proposed airgun array was calculated using the beamforming module in the CASS-GRAB acoustic propagation model (Weinberg, 2004). The directivity pattern was generated for each degree of declination (vertical direction) from + 90° to -90°, every 10 degrees in azimuth (horizontal direction), and at each center frequency of 1/3-octave bands from 10 to 2,000 Hz (**Figure 4**).

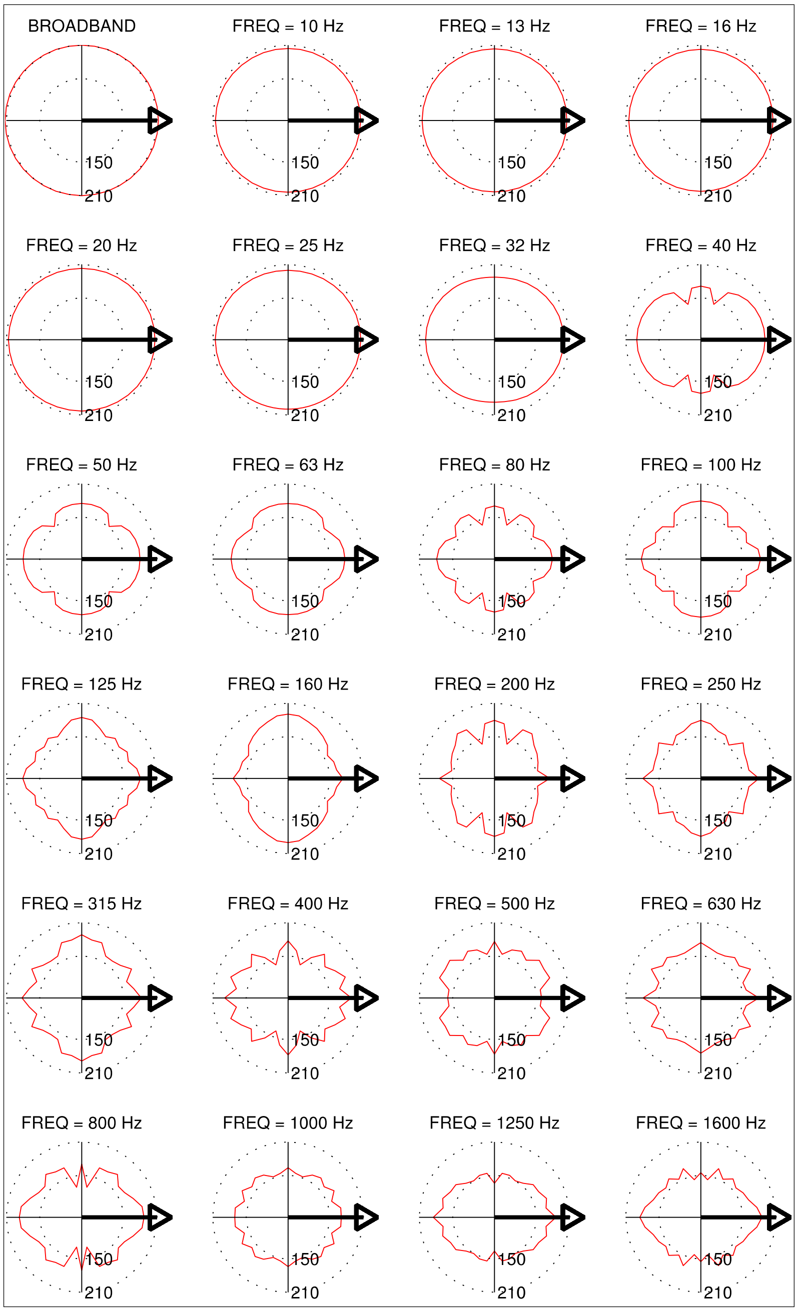

Figure 4. Horizontal directivity patterns (calculated without surface interactions)

3 Acoustic Propagation Model

The acoustic field that would be generated by the proposed airgun array was modeled using the range-dependent acoustic model (RAM). RAM is a parabolic equation (PE) model that incorporates a geoacoustic ocean bottom model (Collins, 1993). Low-frequency propagation modeling in shallow water is commonly regarded as difficult, primarily because of the complexities associated with seafloor bottom interactions. A comparison of measured sound propagation and model predictions found that RAM was able to predict the sound field from a shallow water pile driver with good accuracy (Malme et al., 1998).

Since the bathymetry is bearing dependent (it changes depending on the direction in which the sound is propagating away from the source), the acoustic field at every modeling location for each season was created by combining 36 model runs created at 10° intervals.

4 Environmental Inputs for Acoustic Propagation Modeling

Acoustic propagation modeling requires information on the physical characteristics of the underwater environment. This information includes the sound velocity profile of the water column, the bathymetry, surface interactions which are primarily determined by the roughness of the water surface due to wind, and bottom interactions which include the reflective properties or geologic composition of the seafloor. Eighteen modeling locations were selected that span the acoustic and marine mammal conditions of the proposed seismic survey (**Table 3**; **Figure 5**).

Table 3. Modeling locations

Site No.	Latitude	Longitude	Water depth (m)	Wind Speed (kts)			
				Feb	May	Aug	Nov
1	28.38309	-80.1332	45	14.4	11.7	8.9	14.5
2	28.41155	-79.2786	820	14.4	11.7	8.9	14.5
3	28.42494	-77.1715	1000	14.3	11.5	9.1	14.3
4	32.50479	-78.92262	40	15.6	12.8	10.6	14.3
5	31.89874	-78.1955	650	15.6	12.8	10.4	14.3
6	31.06751	-77.2588	1500	16.1	12.9	10.4	14.4
7	30.12418	-76.1398	2600	15.6	12.1	9.9	14.2
8	34.4633	-76.2763	30	17.0	13.9	10.9	15.1
9	34.17096	-75.776	700	17.5	14.0	11.0	15.3
10	33.84273	-75.2238	3300	17.5	14.0	11.0	15.3
11	33.40949	-74.5035	4200	17.6	13.9	11.0	15.4
12	36.27238	-75.2167	30	15.6	11.1	10.5	14.6
13	36.09425	-74.8044	140	15.6	11.1	10.5	14.6
14	35.85348	-74.2543	2400	17.6	13.9	11.1	15.7
17	38.05702	-73.1276	2200	16.0	9.7	10.5	14.5
18	35.63709	-72.0254	4180	19.0	14.7	11.3	16.4

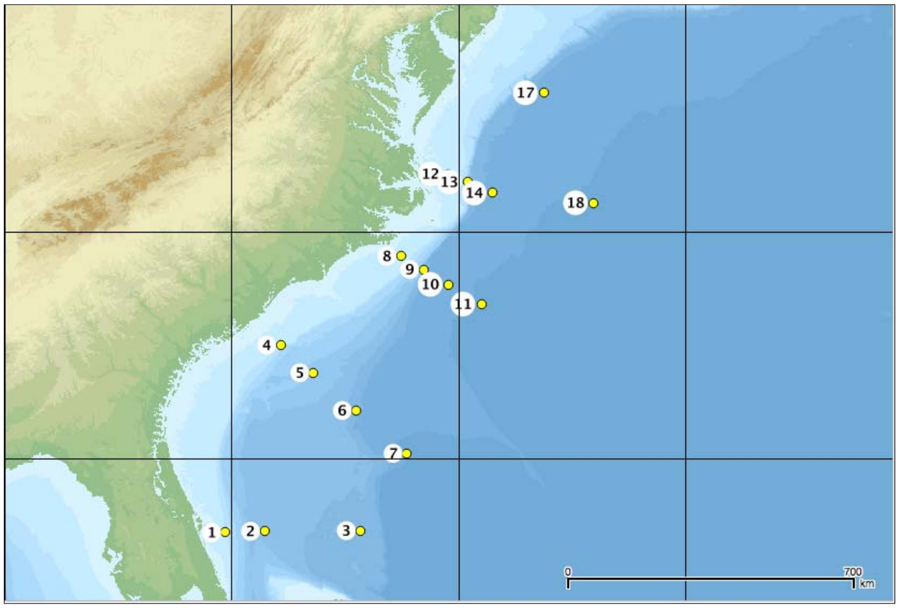

Figure 5. Modeling locations shown with bathymetry

4.1.1 Sound Velocity Profiles

Sound velocity profiles were extracted from the General Digital Environmental Model (GDEM-V) (version 3.0) database for each of the eighteen modeling locations for the months of February (winter) and May (spring) (**Figures 6-7**, respectively). The shallower sites are shown in the left panel; the deeper sites are shown in the right panel.

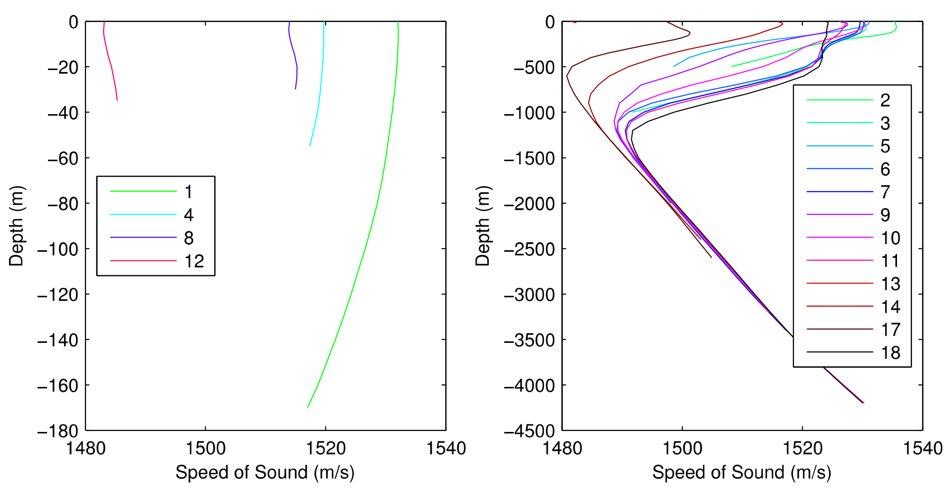

Figure 6. Winter sound velocity profiles for the ten modeling locations

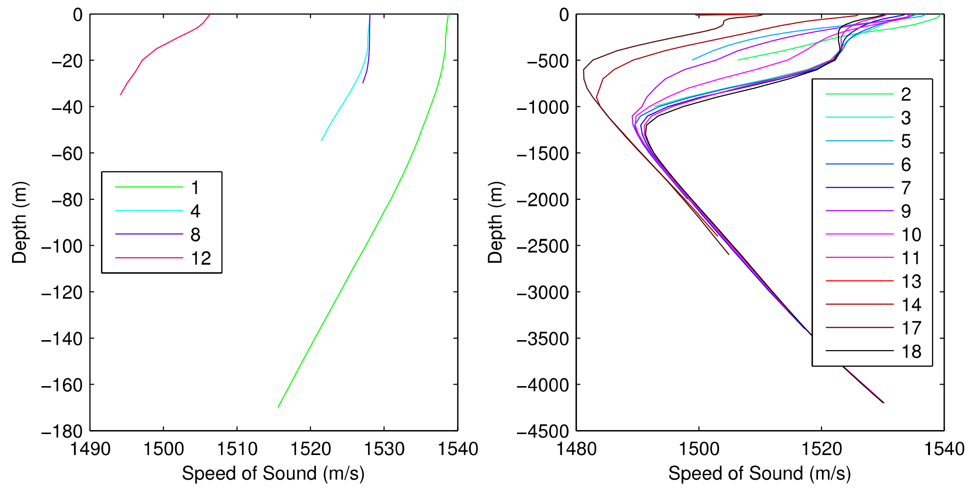

Figure 7. Spring sound velocity profiles for the ten modeling locations

4.1.2 Bathymetry

ETOPO1 is a global relief model of the Earth's surface (Amante and Eakins, 2008). The bathymetry for the modeling locations was extracted from this database, which has a 1° resolution in latitude and longitude (http://www.ngdc.noaa.gov/mgg/global/global.html).

4.1.3 Surface Interactions: Wind Speeds

When sound interacts with the sea surface, there is a loss of acoustic energy. The RAM propagation model requires an input of wind speed to calculate the amount of energy that will be lost with surface interactions. The mean monthly wind speed for the nearest 1° x 1° grid cell to each modeling location was extracted from the Remote Sensing Systems global database of wind speed (Remote Sensing Systems, 2012).

4.1.4 Bottom Interactions: Geoacoustic Model Construction

When sound interacts with the seafloor, acoustic energy is lost. The RAM model represents the seafloor with geoacoustic parameters including the density of each layer of substrate as well as the substrate's compressional and shear wave velocity and attenuation coefficients.

Since the effects of the ocean bottom on the propagation of airgun signals is so important for proper prediction, a more detailed investigation of the bottom properties was undertaken. A set of six core samples was selected for analysis to estimate the geoacoustic parameters. These included data from ODP sites 390, 533 and 603, as well as AMCOR sites 6002, 6004 and 6008 (**Tables 4-9**). The core data supported analysis to a depth of approximately 200 meters. Parameter values for deeper strata were extracted from Appendix D, Section 4.3.2, of the Final Programmatic Environmental Impact Statement for the Atlantic Outer Continental Shelf Proposed Geological and Geophysical Activities: Mid-Atlantic and South Atlantic Planning Areas (http://www.boem.gov/Atlantic-G-G-PEIS/#Final%20PEIS).

Table 4. Geoacoustic model parameters for ODP site 603

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient (dB/lambda)	Shear Wave Attenuation Coefficient (dB/lambda)
0	1520	80	1.51	0.025	0.082
25	1520	120	1.55		
50	1520	160	1.59	0.05	0.9
75	1525	190	1.63		
100	1500	220	1.67	0.08	0.96
125	1570	240	1.70		
150	1550	270	1.74	0.125	1.02
175	1550	290	1.78		
200	1560	310	1.82	0.175	1.07

Table 5. Geoacoustic model parameters for ODP site 533

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient (dB/lambda)	Shear Wave Attenuation Coefficient (dB/lambda)
0	1510	100	1.5	0.05	0.85
25	1540	145	1.7	0.075	0.975
50	1570	170	1.8	0.15	1.1
75	1540	220	1.7	0.08	0.95
100	1555	245	1.7	0.1	0.98
125	1555	275	1.8	0.12	1.02
150	1560	300	1.8	0.12	1.05
175	1575	345	1.8	0.12	1.05
200					

Table 6. Geoacoustic model parameters for ODP site 390

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient (dB/lambda)	Shear Wave Attenuation Coefficient (dB/lambda)
0	1520	80	1.65	0.05	1
25	1520		1.52	0.02	1
50	1520	150	1.57	0.03	1
75	1550	215	1.68	0.1	1
100	1610	280	1.80	0.2	1
125	1700	350	1.90	0.3	1
150	1725	410	2.00	0.4	1
175	1730	470	2.10	0.5	2

Table 7. Geoacoustic model parameters for AMCOR site 6002

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient	Shear Wave Attenuation Coefficient

				(dB/lambda)	(dB/lambda)
0	1650	125	1.80	0.6	2
25	1750	200	1.72	1	2.6
50	1750	235	1.65	1	3
75	1725	270	1.70	0.8	2.8
100	1700	300	1.75	0.9	2.75
125	1750	330	1.81	1	2.75
150	1800	375	1.87	1	2.4
175	1800	415	1.89	0.3	1.5
200	1850	450	1.90	0.4	

Table 8. Geoacoustic model parameters for AMCOR site 6004

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient (dB/lambda)	Shear Wave Attenuation Coefficient (dB/lambda)
0	1700	150	1.8	1.4	3
25	1690	200	1.7	1.35	3.2
50	1670	250	1.75	1.3	3.3
75	1650	260	1.75	0.4	3.4
100	1650	260	1.7	1	3.5
125	1650	250	1.7	1	4
150	1650	250	1.65	1	3.75
175	1675	300	1.65	0.9	3.5
200	1700	350	1.8	1	3

Table 9. Geoacoustic model parameters for AMCOR site 6008

Depth (m)	Compressional Velocity (m/s)	Shear Velocity (m/s)	Density (g/cm^3)	Compressional Attenuation Coefficient (dB/lambda)	Shear Wave Attenuation Coefficient (dB/lambda)
0	1720	220	1.98	0.1	1.2
25	1795	225	1.99	0.16	1.2
50	1970	350	2.00	0.17	1.2
75	2050	570	2.00	0.22	1.2
100	2075	600	2.03	0.72	1.2
125	2080	325	2.05	0.72	2.3
150	2095	650	2.07	0.72	2.3
175	2105	680	2.09	0.72	2.3
200	2120	710	2.10	0.72	2.3

5 Marine Mammal Distributions and Movements

5.1 Distribution and Density Estimates

At the time of this analysis, the best available data on marine mammal density estimates for the western Atlantic Ocean were the U.S. Navy's Navy Operating Area (OPAREA) Density Estimates (NODES) database (Department of the Navy, 2007; Duke SERDP Web Portal, 2014 http://seamap.env.duke.edu/search/?app=serdp). These density estimates are based on the NMFS Southeast Fisheries Science Center (SEFSC) shipboard surveys conducted between 1994 and 2006, and were derived using a model-based approach and statistical analysis of the existing survey data using the model DISTANCE (Buckland et al., 2001). The outputs from the NODES database are two seasonal surface density plots (winter, spring) for each marine mammal species occurring there. The NODES database does not provide data for the most seaward regions of the proposed survey, specifically beyond 200 nmi from shore past the U.S. Exclusive Economic Zone. For those regions, the density estimates from the eastern-most edge where data are known were extrapolated seaward to the spatial extent of the proposed seismic survey. The density estimates were divided into ten zones based on acoustic propagation conditions (**Figures 8**-**9**) and are presented for each species (**Table 10**).

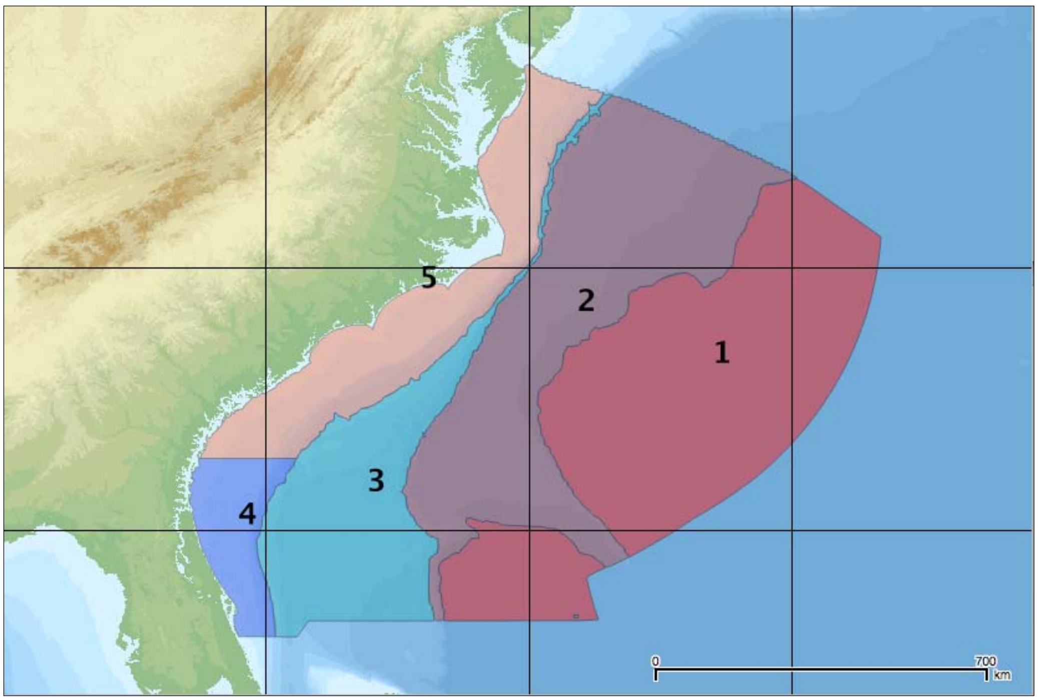

Figure 8. Winter density zones

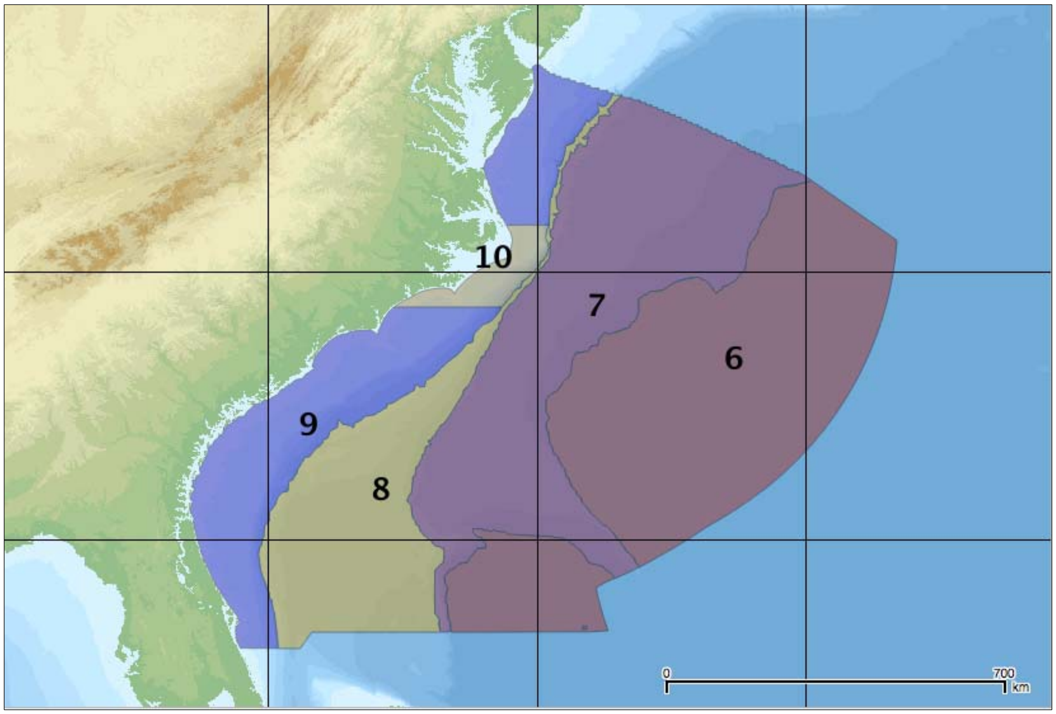

Figure 9. Spring density zones

Table 10. Marine mammal density estimates (animals/100 square kilometers) for the 10 density zones.

	Winter					Spring				
Zone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Mysticetes										
Minke whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Sei whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Bryde’s whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Blue whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fin whale	0.003	0.003	0.015	0.003	0.003	0.003	0.003	0.003	0.015	0.003
North Atlantic right whale	0.000	0.000	0.000	0.111	0.061	0.000	0.000	0.000	0.015	0.015
Humpback whale	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Odontocetes										
Common dolphin	1.593	1.902	5.265	1.593	5.265	1.593	1.902	5.265	5.265	1.593
Pygmy killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Short-finned pilot whale	0.245	2.405	4.383	0.052	0.061	0.073	1.535	4.339	2.557	0.055
Long-finned pilot whale	0.082	0.603	0.556	0.000	0.015	0.023	0.478	0.620	0.364	0.017
Risso's dolphin	0.658	1.313	2.612	0.696	1.934	0.041	1.340	3.215	1.325	0.015
Northern bottlenose whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Pygmy sperm whale	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009
Dwarf sperm whale	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023	0.023
Atlantic white-sided dolphin	0.050	0.041	0.023	0.000	0.038	0.015	0.015	0.009	0.009	0.015
Fraser’s dolphin	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Sowerby's beaked whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Blainville's beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
Gervais' beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
True's beaked whale	0.000	0.093	0.093	0.000	0.000	0.000	0.073	0.082	0.000	0.000
Killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Melon-headed whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Harbor porpoise	0.029	0.023	0.015	0.000	0.023	0.015	0.015	0.009	0.009	0.015
Sperm whale	0.006	0.402	0.530	0.003	0.003	0.006	0.402	0.271	0.003	0.003
False killer whale	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Pantropical spotted dolphin	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649	0.649
Clymene dolphin	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309	0.309
Striped dolphin	0.783	6.733	6.733	0.783	0.967	0.783	6.092	0.783	0.783	0.783
Atlantic spotted dolphin	0.061	6.028	5.446	8.497	9.225	0.061	4.572	2.563	5.879	7.333
Spinner dolphin	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Rough-toothed dolphin	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Bottlenose dolphin	0.521	1.203	8.238	8.238	1.884	0.521	7.557	8.579	0.862	0.862
Cuvier's beaked whale	0.003	0.644	0.646	0.003	0.003	0.003	0.504	0.577	0.003	0.003
Pinnipeds										
Hooded seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Harbor seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Gray seal	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

5.2 Animal Movement Parameters

Animals move through four dimensions: 3D space plus time. Several movement parameters are used in AIM to accurately represent real animal movements. A typical marine mammal dive pattern consists of two phases; the first is a shallow respiratory sequence, which is followed by a deeper, longer dive (**Figure 10**).

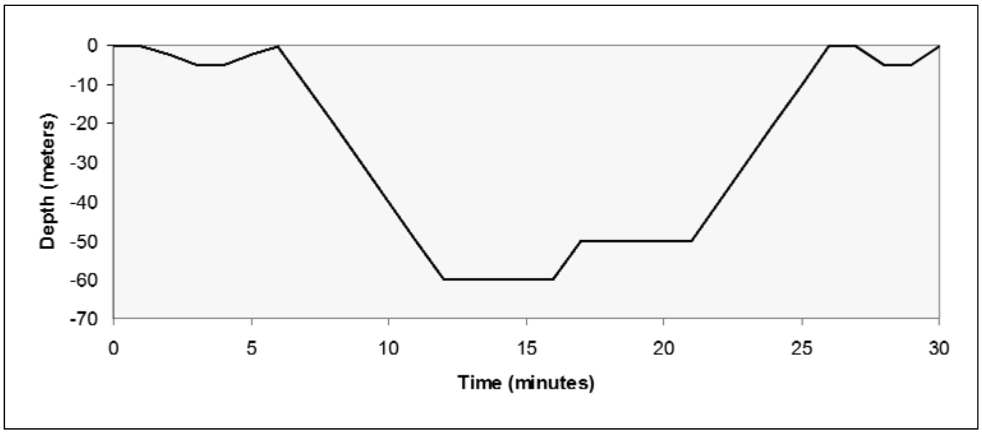

Figure 10. Typical marine mammal dive pattern

The behaviors described in these two phases are represented in the model with two rows of parameters (**Figure 11**). The top row characterizes the shallow, respiratory dive in which the animal can dive from the surface (top depth = 0 m) to a maximum bottom depth of 5 m for a duration of between 5 and 8 minutes. The second row describes the second phase of the dive. In this phase, the animal can dive to a depth between 50 and 75 m (164 and 246 ft) for a duration of between 10 and 15 minutes. In this example (**Figure 10**), the animal spends time at both 60 and 50 m (197 and 164 ft) before surfacing. The pattern then repeats.

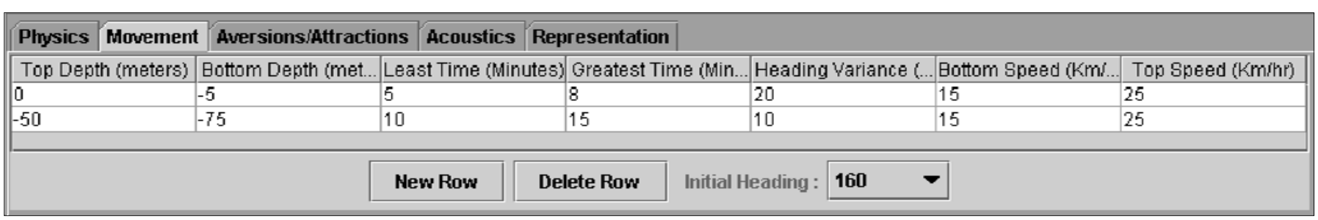

Figure 11. Parameters used to specify the dive pattern shown in Figure 14

5.2.1 Heading Variance

The horizontal component of the course is handled with the “heading variance” term. It allows the animal to turn up to a certain number of degrees at each movement step. In this case, the animal can change course 20 degrees during the shallow dive, but only 10 degrees during the deep dive (**Figure 11**). This example is for a narrowly constrained set of variables, appropriate for a migratory animal.

There are few published data that summarize marine mammal movement in terms of heading variance, or the amount of course change per unit time. The default setting allows the course to deviate between 0 and 30 degrees per minute.

5.2.2 Aversions

In addition to movement patterns, the animats can be programmed to avoid certain environmental situations. For example, an animal can be constrained to remain within a particular depth regime. The following example (**Figure 12**) constrains the animal to water depths between 2,000 and 5,000 m (6,562 and 16,404 ft). In the analysis for this project, normally deep-water species were allowed to move into waters as shallow as 100 m (328 ft).

There are a number of potential aversion variables that can be used to build an animat's behavioral pattern. For this modeling effort, they consisted of bathymetric aversions and modeled area boundary aversions. At the end of each time step, each animat "evaluates" its environment within the context of its defined behavioral parameters. If an environmental variable has exceeded the user-specified boundary value (e.g., water too shallow), then the animat will alter its course to react, or avert, to the environment.

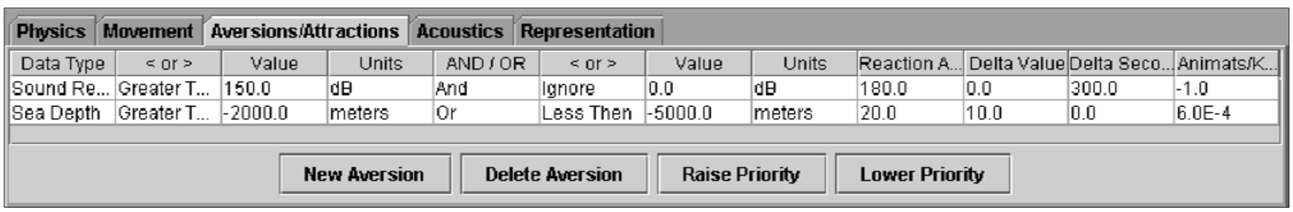

Figure 12. Example aversions that restrict an animat to water depths between 2,000 and 5,000 m (6,562 and 16,404 ft)

5.2.3 Species Behavior Parameters

The specific animal behavioral parameters that were used in this analysis are provided below. Where the "Surfacing/Dive Angle" column is empty, there were no meaningful data available so 75° was used as a default value. Under the "Speed Distribution" column, "Normal" indicates that the distribution of speed values between the limits was normally distributed. Under the "Depth Limit/Reaction Angle" column, the first number indicates the minimum depth limit in meters, and "reflect" indicates that if an animat moves to that shallow water limit, it will move away from the shallow water and back into deeper water.

5.2.3.1 Minke Whale

Model Parameters

	Min/Max Surface Time (min)	**Surface/Dive Angle**	**Dive Depth (m) Min/Max (Percentage)**	**Min/Max Dive Time (min)**	**Heading Variance (angle/time)**	**Min/Max Speed (km/hr)**	**Speed Distribution (α,β)**	**Depth Limit/Reaction Angle**
Minke Whale	1/3	75º	20/100	2/6	Surface 45 Dive 20	1/18	Gamma (3.25,2)	10/reflect

Surface Time

A mean surface time of 1.72 minutes, with a range of 0.63-2.35 minutes was reported by (Stern, 1992).

Dive Depth

Inferred from other species, however reduced in depth, since minkes are likely to be pelagic feeders, feeding on species found near the surface (Olsen and Holst, 2001).

Dive Time

The mean dive time reported by (Stern, 1992) was 4.43 (+/- 2.7) minutes. Dive times measured off Norway range from approximately 1-6 minutes (Joyce et al., 1989). Dive times also show small diel and seasonal variability (Stockin et al., 2001), but the variability is small enough to be considered not significant for AIM modeling. Dive times were non-normal (Øien et al., 1990).

Speed

The mean speed value for minke whales in Monterey Bay was 4.5 (+/- 3.45) knots (8.3 +/- 6.4 km/hr) (Stern, 1992). Satellite tagging studies have shown movement of up to 79 km/day (49 mi/day) (3.3 km/hr [2.1 mi/hr]). Minke whales being pursued by killer whales were able to swim at 15-30 km/hr (Ford et al., 2005).

A gamma function was fit to the available speed data. The modal speed of this function is 4.5 km/hr (2.8 mi/hr), matching the Stern (1992) data, and has a maximum of 18 km/hr (11 mi/hr), somewhat less than the maximum speed achievable (30 km/hr [19 mi/hr]), observed during predation. “Cruising” minkes have been reported at 3.25 m/s (10.66 ft/s) (Blix and Folkow, 1995).

Habitat

Minke whales in Monterey Bay were reported to be in a median depth of 48.6 m (159.4 ft) (Stern, 1992). They are known to move into very shallow water as well as deep oceanic basins. The 10-m (33-ft) limit and reflection aversion are intended to let minkes roam freely, but to stay off the beach.

Group Size

Mean group size in the Antarctic was 1.6 individuals (Blix and Folkow, 1995).

Residency

Foraging minke whales have been shown to exhibit small scale site fidelity (Morris and Tscherter, 2006). Therefore, foraging minke whales should have their course change parameters set to be variable to allow for small net movements.

5.2.3.2 Sei/Bryde’s Whale

There is a paucity of data for these species. Since they are similar in size, data for both species have been pooled to derive parameters for these two species.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Sei/Bryde's Whale	1/1	90/75º	10/40 (80) 50/267 (20)	2/11	30/300 (50%) 90/300 (50%)	1/20	5/1

Surface Time

No direct data available, fin whale values used.

Dive Depth

A limited number of Bryde's whales have been tagged with time-depth recorders (TDRs) (Alves et al., 2010). Shallow dives, less than 40 m (131 ft) were recorded 85 percent of the time, while deep dives occurred 15 percent of the time. The maximum dive depth reported was 267 m (876 ft).

Two distinct dive types were noted for Bryde's whales. Both performed a long series of shallow dives of less than 40 m (131 ft) until 1.5 hours before sunset. The animals then made the deepest dives. During the night, sequential deep dives took place. Foraging lunges were recorded during about half of these night time dives.

Dive Time

Sei whale dive times ranged between 0.75 and 11 minutes, with a mean duration of 1.5 minutes (Schilling et al., 1992). Most of the dives were short in duration, presumably because they were associated with surface or near-surface foraging. The same paper reported surface times that ranged between 2 s and 15 minutes. The maximum dive time reported for two Bryde's whales was 9.4 minutes (Alves et al., 2010) with mean durations of 4-6 minutes.

Heading Variance

Observations of foraging sei whales found that they had a very high reorientation rate, frequently resulting in minimal net movement (Schilling et al., 1992).

Speed

A tagging study found an overall speed of advance for sei whales was 4.6 km/hr (2.9 mi/hr) (Brown, 1977). The highest speed reported for a Bryde's whale was 20 km/hr (Cummings, 1985). A Bryde's whale being attacked by killer whales traveled ~9 km in 94 minutes, with most of the travel occurring in first 50 minutes, producing an estimated speed of 10.8 km/hr (6.7 mi/hr) (Silber et al., 1990). The maximum speed of sei whales reported from a satellite tracking study was 7.6 m/s (25 ft/s), although the distribution of speeds was highly skewed toward lower values (Olsen et al., 2009). The speed parameters used in AIM are 0-20 km/hr (0-12.4 mi/hr), using a gamma distribution with alpha and beta parameters of 5 and 1. These values produce the following distribution, which covers the reported range of speed (Olsen et al., 2009) and approximated the mean value reported by Brown (1977).

Habitat

Sei whales are known to feed on shallow banks such as Stellwagen Bank (Kenney and Winn, 1986). Therefore, sei and Bryde's whales are allowed to move into shallow water.

Group Size

Sei whales in the Gulf of Maine were seen in groups of 1-6 animals with a mean group size of 1.8 whales (Schilling et al., 1992). Bryde's whales in the Gulf of California were seen in groups of 1-2 animals, with a mean size of 1.2 whales (Silber et al., 1994).

5.2.3.3 Blue Whale

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Blue Whale (non-foraging)	1/2	75º	20/100	2/18	30/300 (50%) 90/300 (50%)	3/14	Norm.	100/reflect
Blue Whale (foraging)	1/2	75º	20/100 (50) 100/300 (50)	2/18 4/18	30/300 90/90	3/14	Norm.	100/reflect

Surface Time

Only one of four satellite tagged blue whales reported surface intervals of 7-90 s with a mean of 48 s. The other three did not report intervals >60 s, indicating that the surface time was short (Lagerquist et al., 2000).

Dive Depth

Croll et al. (2001) reported a mean dive depth of 140 m (459 ft) (+/- 46.01) for non-foraging animals, while foraging whales had a mean dive depth of 67.6 m (221.8 ft) (+/- 51.46). Satellite tagged whales off California had a maximum dive depth of 192 m (630 ft) (Lagerquist et al., 2000). The distribution of dive depths was bimodal, as typified by the plot below (note that this is from one animal). A series of blue whales had Crittercams attached to them off California and Mexico. The maximum dive depth reported was 293 m (961 ft) (Calambokidis et al., 2008). Many of these animals had deep feeding dives, with lunges occurring 200-260 m (656-853 ft). Notably, one animal transitioned from deep feeding dives of decreasing depth as the sun set to shallow non-feeding dives. This indicated that there may be a diurnal character to some blue whale behavior.

Separate animats for foraging and non-foraging blue whales were created. Foraging animats will have a 50:50 distribution between deep dives (200-300 m [656-984 ft]) and shallower dives (20-100 m [66-328 ft]).

Dive Time

Mean dive times of 4.3, 7.8, 4.9 5.7, 10, and 7 minutes have been reported for blue whales (Laurie, 1933; Doi, 1974; Lockyer, 1976; Croll et al., 1998; Croll et al., 2001). The best estimate of the maximum dive time is 14.7 minutes (Croll et al., 2001), although a max time of 30 minutes was reported by (Laurie, 1933). The longest dive reported for satellite tagged whales was 18 minutes, although the mean dive times for all whales was 5.8 (+/- 1.5) minutes (Lagerquist et al., 2000).

Speed

Dive descent rates of 1.26 m/s (4.13 ft/s) have been recorded (Williams et al., 2000). A mean surface speed of 1.25 m/s (4.10 ft/s) with a maximum speed of 2.0 m/s (6.6 ft/s) was reported from satellite tags (Mate et al., 1999), although satellite data tend to smooth the track and therefore underestimate speed. A second satellite tag study found straight-line speed (under) estimates from 1.3 to 14.2 km/hr (0.8 to 8.8 mi/hr).

Group Size

Blue whales in the Eastern Tropical Pacific had a modal group size of one, although pods of two were somewhat common (Reilly and Thayer, 1990). The mean group size of blue whales off Australia (*B. m. brevicauda*) was 1.55 (Gill, 2002).

5.2.3.4 Fin Whale

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Fin Whale	1/1	75º	20/250 (90) 250/470 (10)	5/8 1/20	20	1/16	Norm.	30/reflect

Surface Time

Remarkably good data for surface times exist for fin whales. A log survivorship analysis of all inter-blow intervals was used to determine an inflection point of 28 and 31 s between surface and dive activity for feeding and non-feeding animals, respectively (Kopelman and Sadove, 1995). The mean surface duration for fin whales without boats present off Maine was 54.63 s (standard deviation [SD]=59.61) while dive times were 200.84 s (SD=192.91) (Stone et al., 1992).

Dive Depth

Foraging fin whales had mean dive depths of 97.9 +/- 32.59 m, while traveling fin whales had mean dive depths of 59.3 +/- 29.67 m (Croll et al., 2001). Migrating fin whales were determined to have a maximal dive depth of 364 m (1,194 ft), (Charif et al., 2002). Fin whales in the Mediterranean Sea typically dove to ~100 m (~382 ft), and occasionally dove to 470 m (1,542 ft) or more (Panigada et al., 1999), however these are unusually deep dives. The animats here model the more typical dive pattern 90 percent of the time. Foraging fin whales off California had a mean maximum dive depth of 248 m (814 ft) (Goldbogen et al., 2006). Based on this study, the most frequent AIM dive depth is extended to 250 m.

Dive Time

Foraging fin whales had mean dive times of 6.3 +/- 1.53 minutes, while traveling fin whales had mean dive times of 4.2 +/- 1.67 minutes (Croll et al., 2001). The maximum dive time observed was 16.9 minutes. Fin whales off the east coast of the U.S. were observed to have mean dive times of 2.9 minutes. Ranges for feeding animals ranged from 29 to 1,001 s, while non-feeding animals had longer dives between 32 and 1,212 s (Kopelman and Sadove, 1995). Panigada et al. (1999) found that shallow (<100 m [<328 ft]) dives had a mean dive time of 7.1 minutes, while deeper dives had dive times of 11.7 and 12.6 minutes. Fin whales foraging on Jeffrey's Ledge in the Gulf of Maine had mean dive times of 5.83-5.89 minutes (Ramirez et al., 2006).

Speed

Watkins (1981) reported a mean speed of 10 km/hr (6 mi/hr) ranging from 1 to 16 km/hr (0.6 to 10 mi/hr) with bursts of 20 km/hr (12 mi/hr) reported. Mean descent speeds of 3.2 m/s (10.5 ft/s) (SD=1.82) and ascent speeds of 2.1 m/s (6.9 ft/s) (SD=0.82) have been reported from fin whales in the Mediterranean (Panigada et al., 1999).

Habitat

Fin whales are found feeding on shallow banks and in bays (Woodley and Gaskin, 1996) as well as in the abyssal plains of the ocean (Watkins, 1981). Fin whales are allowed to move into shallow water in AIM, with a 30-m (98-ft) inshore limit to keep them out of the very shallow waters.

Group Size

Fin whales in the Gulf of Mexico had a mean group size of 5.7 with a range in group sizes from 1 to 50 (Silber et al., 1994). In the Mediterranean Sea the mean group size over a number of years was 1.75 animals (Panigada et al., 2005).

5.2.3.5 North Atlantic Right Whale

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)
Right Whale	4/5	75º	113/130	11/13	30	3/6	Norm.

Surface Time

Mean surface time for right whales was less than 60 s (Winn et al., 1995). Therefore a one minute surface time was used for AIM.

Dive Depth

Right whale feeding dives in the northwest Atlantic were characterized by rapid descent to depths between 80 and 175 m (262 and 574 ft). The median depth was 119 m (390 ft) with a 90 percent confidence interval between 113 and 130 m (371 and 427 ft) (Baumgartner and Mate, 2003). This 90 percent confidence range was used for the dive depth range. In a nearby area, right whales dove to depths between approximately 120 and 180 m (394 and 591 ft) (Nowacek et al., 2004).

Dive Time

The median dive time for foraging right whales was 12.65 minutes, with a 95 percent confidence interval of 11.4-12.9 minutes (Baumgartner and Mate, 2003).

Speed

Descent speed of diving right whales had a 95 percent confidence interval of 1.3-1.5 m/s (4.3-4.5 ft/s) while the ascent speed was 1.4-1.7 m/s (4.6-5.6 ft/s) (Baumgartner and Mate, 2003). Radio tagged whales that remained in the Bay of Fundy had a mean speed of 1.1 km/hr while those that left the bay had a mean speed of 3.5 km/hr (2.2 mi/hr) (Mate et al., 1997). Note that radio tagging tends to underestimate whale speed, since the data greatly smooth the recorded course of the animal.

Habitat

Northern right whales are currently found in the northwest Atlantic Ocean and the North Pacific. In the North Atlantic, they are found offshore eastern Canada and the U.S. northeast coast during the summer foraging season. They migrate along the coast and their breeding area is in the shallow waters offshore of Florida and Georgia. It is believed that a portion of the population migrates to an undiscovered location.

Group Size

The group size of surface active groups (SAGs) in the Bay of Fundy ranged from 2 to 15 animals (Parks and Tyack, 2005).

5.2.3.6 Humpback Whale (Feeding)

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Feeding Humpback Whale	1/2	75º	10/60 (20) 40/100 (75) 100/150 (5)	5/10	90/300 90/90 90/90	1/8	Norm.	(Min = 100)/ reflect

Surface Time

Approximately 65 percent of all surfacing observed in Alaska were 2 minutes in length or less (Dolphin, 1987a). Surface times in Hawaii are similar with the exception of surface active groups (Frankel, pers. obs.).

Dive Depth

Humpback whale dive depths have been measured on the feeding grounds. Seventy-five percent of their dives were to 40 m (131 ft) or less with a maximum depth of 150 m (492 ft) (Dolphin, 1988). Dive depth appears to be determined by prey distribution. Whales in this study were primarily foraging upon euphausiids. There is also a strong correlation of dive depth and dive time and is described by the following equation (Dolphin, 1987a):

Time (s) = 0.52 * depth (m) +3.95, r^2 = 0.93

Feeding humpbacks off Kodiak Alaska had a mean maximum depth of 106.2 m (348 ft) with 62 percent of the dives occurring between 92 and 120 m (302 and 394 ft) with a maximum of ~160 m (~348 ft) (Witteveen et al., 2008). The humpbacks appeared to be feeding largely on capelin and pollock.

There are strong differences in the data between these two studies. This difference may reflect the distribution of prey rather than behavioral abilities of the whales.

Dive Time

The maximum of the continuous portion of the distribution of dive times was 15 minutes (Dolphin, 1987a). The distribution was skewed toward shorter dives. Several dive steps can be programmed in AIM to capture this variability.

Heading Variance

Satellite tracking of feeding humpback whales in the Southern Ocean showed very erratic travel, and animals frequently remained in a specific area for up to a week at a time. There were periodic movements between feeding areas (Dalla Rosa et al., 2008). Therefore, the heading variance for feeding humpbacks was set relatively high, for 80 percent of the time. Twenty percent of the time the heading variance was set as low to simulate movement between feeding areas.

Speed

Mean speeds for humpbacks are near 4.5 km/hr (2.8 mi/hr). The measured range is 2-11.4 km/hr (1-7 mi/hr) (excluding stationary pods) (Gabriele et al., 1996). Feeding humpbacks in the Southern Ocean had mean measured speeds between 2.26 and 4.03 km/hr (1.4 and 2.5 mi/hr) (Dalla Rosa et al., 2008). These values were derived from short segments of satellite tracking data; therefore, they are likely underestimates of speed.

Ascent rates during dives range from 1.5 to 2.5 m/s (4.8 to 8.2 ft) while descent rates range between 1.25 and 2 m/s (4.1 and 6.6 ft/s) (Dolphin, 1987b). The mean speed for all pod types in Glacier Bay was 3.31 km/hr (1 mi/hr) (Baker and Herman, 1989).

Habitat

Migrating humpbacks swim both along the coast (California population) as well as through the abyssal plains. Humpbacks swim along coastal regions are known to swim further offshore than gray whales. Therefore, the minimum depth for this species has been set at 100 m (328 ft).

Group Size

Ninety-six percent of 27,252 pods in the Gulf of Maine were composed of 1-3 animals with a modal size of one adult (Clapham, 1993).

5.2.3.7 Humpback Whale (Winter Grounds: Singer)

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Humpback Singer	1/1	75º	10/25	5/25	20	0/1	Norm.	>1,000/reflect

Surface Time

Singers typically surface for <1 minute. Singers in the Caribbean blew between 2 and 8 times per surfacing (Chu, 1988).

Dive Depth

Humpback singers have relatively shallow depths.

Dive Time

Dive times typically range from 10 to 25 minutes. Observations of 20 singers in the Caribbean found dive times between five and 20 minutes in duration (Chu, 1988).

Heading Variance

The heading variance is set very low for singers. While traveling very slow to stationary, they tend to swim along the coast.

Speed

Most singers are stationary although very few move at high speeds.

Habitat

On the wintering grounds most singers are found within the 100 fathom contour, but a few are found in deeper waters.

Group Size

The vast majority of singers are found alone. The largest pod reported containing a singer was four animals (Frankel et al., 1995).

5.2.3.8 Humpback Whale (Migrating)

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Migrating Humpback Whale	1/2	75º	10/40	5/10	10	2/10	Norm.	(Min =100)/ reflect

Dive Depth

Humpback whale dive depths have been measured on the feeding grounds. Seventy-five percent of their dives were to 40 m (131 ft) or less (Dolphin, 1988). It is likely that migrating animals would also predominantly dive to these shallow depths. Humpbacks foraging off California had a mean maximum dive depth of 156 m (512 ft) (Goldbogen et al., 2008).

Dive Time

Surface times range between 1 and 2 minutes while dive times range between 5 and 10 minutes (Gabriele et al., 1996). Foraging humpbacks off California had mean dive times of 7.8 +/- 2.0 minutes (Goldbogen et al., 2008).

Heading Variance

The heading variance was set very low for migrating animals. Most non-competitive group breeding animals also have linear travel. Migrating humpbacks swam very close to magnetic north from Hawaii with very little deviation (Mate et al., 1998).

Speed

Mean speeds for humpbacks are near 4.5 km/hr (2.8 mi/hr). The measured range is 2-11.4 km/hr (1.2-7.1 mi/hr) (excluding stationary pods) (Gabriele et al., 1996). Satellite tracked migrating humpback whales moved at a minimum of 150 km/day (93 mi/day) (6.25 km/hr [3.9 mi/hr]) for a mother and calf pod, while another two whales moved 110 km/day (68 mi/day) (4.5 km/hr [2.8 mi/hr]). Humpbacks off Australia were estimated to migrate at a mean speed of 8 km/hr (5 mi/hr), with a range between 4.8 and 14.2 km/hr (3 and 9 mi/hr) (Chittleborough, 1953). More recent studies of Australian humpbacks found a mean northern migration speed of 5.47 km/hr (3.4 mi/hr), while the southern migration speed had a mean of 5.02 km/hr (3.12 mi/hr) for non-calf pods, while calf pods had mean speeds of 5.03 and 4.25 km/hr respectively (Chaudry, 2006).

Habitat

Migrating humpbacks swim both along the coast (California population) as well as through the abyssal plains. Humpbacks swim along coastal regions are known to swim further offshore than gray whales. Therefore, the minimum depth for this species has been set at 100 m (328 ft). Non-calf pods migrating off Australian had a mean offshore distance of 3,177 m (10,423 ft) during the northern migration and 2,560 m (8,399 ft) during the southern migration. Calf pods migrated “significantly” closer to shore (Chaudry, 2006).

5.2.3.9 Common Dolphin

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Common Dolphin	1/1	75º	50/200	1/5	30	2/9	Norm.	100-1,000/ reflect

Dive Depth

Dive depths are reported to be between 50 and 200 m (164 and 656 ft) (Evans, 1994).

Dive Time

The maximum dive time reported was five minutes (Heyning and Perrin, 1994).

Speed

The maximum sustainable speed for common dolphins was measured at 2.5 m/s (8.2 ft/s) (9 km/hr [5.6 mi/hr]) (Hui, 1987).

Habitat

Common dolphins off the NE United States were concentrated along the shelf edge between 100 and 200 m (328 and 656 ft) (Selzer and Payne, 1988). In the Mediterranean common dolphins were found in waters between 25 and 1,300 m (82 and 4,265 ft) deep with 95 percent of the animals in water between 247 and 326 m (810 and 1,070 ft) (Cañadas et al., 2002).

Group Size

Common dolphins in the Gulf of California were found in groups of 4-1,100 animals, with a mean size of 254.3 dolphins (Silber et al., 1994). Off the Pacific Coast of Costa Rica, the mean group size was 220.67 (SD=220.6) (May-Collado et al., 2005).

5.2.3.10 Blackfish: False Killer Whale, Pygmy Killer Whale, Melon-headed Whale

Studies describing the movements and diving patterns of these animals are rare and sparse. Therefore, they have been combined into a single "blackfish" category.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
False/Pygmy killer whales	1/1	75º	5/50 (80) 50/100 (20)	2/12	30	2/22.4	Gamma.	200/reflect

Surface Time

Individual melon-headed whales spend less than one minute on the surface although the group may remain near the surface for long periods of time (Frankel, pers. obs.).

Dive Depth

The maximum dive depth of a single false killer whale off the Madeira Islands was 72 m (236 ft). Most of the time was spent at depths deeper than 20 m (66 ft) and the dives were V-shaped (Alves et al., 2006). Three false killer whales in Hawaii had shallow dives as well with maximum depths of 22, 52, and 53 m (72, 171, and 174 ft) (Ligon and Baird, 2001). It should be noted that these animals were feeding on fish.

Dive Time

No directly measured data were available for "blackfish" whales so data from pilot whales were used for dive time.

Speed

Maximum speed recorded for false killer whales was 28.8 km/hr (17.9 mi/hr) (Rohr et al., 2002), although the typical cruising speed is typically 20-24 percent less than the maximum speed (Fish and Rohr, 1999). This "typical" maximum of 22 km/hr (14 mi/hr) was used as the maximum speed for AIM.

Habitat

False killer whales off the Madeira Islands were found in water depths from 900 to 2,000 m (900 to 6,562 ft) (Alves et al., 2006).

Group Size

False killer whales in the Gulf of Mexico had group sizes between 20 and 35 (mean=27.5, standard error [SE]=7.5, n=2) (Mullin et al., 2004). False killer whales off Costa Rica had a mean group size of 36.16 (+/- 52.38) (May-Collado et al., 2005).

5.2.3.11 Short-finned and Long-finned Pilot Whales

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Pilot Whales	1/1	75º	5/100 (80) 10/1,000 (20)	1/10 5/21	30	2/12	Norm.	200/reflect

Surface Time

A rehabilitated long-finned pilot whale in the North Atlantic was equipped with a satellite tag and a TDR. The log survivorship plot of dive time from this animal had an inflection point at about 40 s (Mate et al., 2005). The authors did not feel that this qualified as a breakpoint to separate surface and dive behavior. However, it does suggest that most surface intervals are less than one minute.

Dive Depth

Long-finned pilot whales in the Mediterranean were observed to display considerable diurnal variation in their dive depths. During the day, they never dove to more than 16 m (52 ft). However, at night, they dove to maximum depths of 360 and 648 m (1,181 and 2,126 ft) with mean depth of 308 and 416 m (1,011 and 1,365 ft) (Baird et al., 2002). Rehabilitated long-finned pilot whales dove to 312 m (1,024 ft) on Georges Bank which has a depth of 360 m (1,181 ft), so these values should not be taken as the maximum. The distribution of dive depths was also skewed toward lower values (Nawojchik et al., 2003).

Short-finned pilot whales off the Canary Islands had maximum depth of 1,019 m (3,343 ft) (Aguilar Soto et al., 2008). The majority of these were to depths of less than 100 m

(328 ft) while the remainder of depths were approximately evenly distributed between 100 and 1,000 m (328 and 3,281 ft).

Dive Time

Baird et al. (2002) reported on dives of two individual long-finned pilot whales and dive times varied between 2.14 and 12.7 minutes during the night. During the day animals spent all of their time in the top 16 m (52 ft).

A rehabilitated long-finned pilot whale in the North Atlantic had dive times between 1 and 6 minutes (Mate et al., 2005). Other rehabilitated long-finned whales were reported to dive to at least 25 minutes although the distribution is skewed toward shorter dives with most lasting about two minutes (Nawojchik et al., 2003). Long-finned pilot whales off the Faroe Islands never dove longer than 18 minutes (Heide-Jørgensen et al., 2002).

Short-finned pilot whales off the Canary Islands had maximum foraging dive times of 21 minutes (Aguilar Soto et al., 2008). They demonstrated a near-linear relationship between dive depth and dive duration. Therefore shallow dives had times ranging between 1 and 10 minutes, while deep dives were set to have times between 5 and 21 minutes.

Speed

Shane (1995) reported a minimum speed of 2 km/hr (1.24 mi/hr) and a maximum of 12 km/hr (7.5 mi/hr) for pilot whales. During the day in the Mediterranean, animals slowly swam, with mean values for two animals of 2.85 and 3.18 km/hr (1.8 and 2 mi/hr), while at night, they swam faster at 6.83 and 5.48 km/hr (4.24 and 3.4 mi/hr) (Baird et al., 2002). A single satellite tracked long-finned pilot whale had a minimum speed of 1.4 km/hr (0.9 mi/hr) (Mate et al., 2005). The speed of traveling pilot whales (*G. scammoni*) was estimated at 4-5 knots (Norris and Prescott, 1961, cited in Mate et al., 2005). Vertical dive speeds of three TDR tagged long-finned pilot whales ranged from 0.79 to 3.38 m/s (2.6 to 11.1 ft/s) with a mean of 1.99 m/s (6.5 ft/s) (Heide-Jørgensen et al., 2002).

Habitat

The minimum water depth for pilot whales in the Gulf of Mexico was 246 m (807 ft) (Davis et al., 1998), while off of Spain, they preferred water deeper than 600 m (1,969 ft) (Cañadas et al., 2002).

Group Size

Short-finned pilot whales in the Gulf of Mexico ranged in group size between 5 and 50 (mean=20.4, SE=3.6, n=11) (Mullin et al., 2004). Off the Pacific Coast of Costa Rica the mean group size of pilot whales was 14.22 individuals (SD=12.06) (May-Collado et al., 2005).

5.2.3.12 Risso's Dolphin

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Risso's Dolphin	1/3	75º	150/1,000	2/12	30	2/12	Norm.	150/reflect

Dive Depth

Dive depths of 150-1,000 m (492-3,281 ft) were inferred from the Risso's squid-eating habits and from similar species.

Dive Time

No data on dive times could be found. The values for blackfish were used which have a similar ecological niche.

Speed

Risso's dolphins off Santa Catalina Island were reported to have speeds ranging between 2 and 12 km/hr (1.24 and 7.5 mi/hr) (Shane, 1995).

Habitat

Risso's dolphins were seen in water deeper than 150 m (492 ft) in the Gulf of Mexico, most often observed between 300 and 750 m (984 and 2,461 ft) (Davis et al., 1998). Off Chile they were seen in waters deeper than 1,000 m (3,281 ft) (Olavarria et al., 2001) and off Spain, they were found deeper than 600 m (1,969 ft) (Cañadas et al., 2002). In all cases this association seems to be driven by the local oceanographic upwelling conditions that increase primary productivity.

Group Size

In the Pacific group sizes were measured between 1 and 220 animals with a geometric mean of 10.7. An estimated 76.4 percent of the groups contained fewer than 20 animals (Leatherwood et al., 1980). Group sizes in the Gulf of Mexico ranged between 2 and 78 animals with a mean of 12.7 (SE=2.0, n=39) (Mullin et al., 2004). The mean group size off the Pacific Coast of Costa Rica was 11.57 (SD=9.64) (May-Collado et al., 2005).

5.2.3.13 Large Beaked Whales

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Berardius	1/7	75º	800/1,453 (90) 50/200 (10)	48/68 12/70	30/300 (50) 90/300 (50)	3/6	Norm.	253/reflect

Surface Time

Surface times in Arnoux's beaked whales ranged from 1.2 to 6.8 minutes (Hobson and Martin, 1996). Sowerby's beaked whales had surface times of 1-2 minutes during which they would blow 6-8 times (Hooker and Baird, 1999a).

Dive Depth

The minimum and maximum dive depth measured for a beaked whale was 120 and 1,453 m (394 and 4,767 ft) respectively (Hooker and Baird, 1999b). *Ziphius* tagged off the Canary Islands had foraging dives between 824 and 1,267 m (2,703 and 4,157 ft) while

Blainsville's beaked whales dove to depths between 655 and 975 m (2,149 and 3,199 ft) (Johnson et al., 2004).

Northern bottlenose whales performed shallow dives with a range of 41-332 m (135-1,089 ft) (n=33), while deep dives ranged from 493 to 1,453 m (1,617 to 4,767 ft) (n=23). Dive depth and dive duration were strongly correlated (Hooker and Baird, 1999b).

Blainsville's beaked whales in Hawaii performed dives to mid-water depth (100-600 m [328-1,969 ft]) approximately six times more frequently than at night. Dives deeper than 800 m (2,625 ft had no diurnal difference (Baird et al., 2008).

Dive Time

The minimum and maximum dive time measured was 16 and 70.5 minutes, respectively (Hooker and Baird, 1999b). Sowerby's beaked whales had dives between 12 and (at least) 28 minutes in the Gully in Canada (Hooker and Baird, 1999a). Arnoux's beaked whale had modal dive times between 35-65 minutes (mean=46.4 min, SD=13.1), with a maximum dive time of at least 70 minutes (Hobson and Martin, 1996). Tagging results with Cuvier's beaked whale had one animal diving for 50 minutes (Johnson et al., 2004). Mesoplodon stejnegeri were observed to dive for "10-15 minutes" in Alaska (Loughlin, 1982).

Blainsville's beaked whales and Cuvier's beaked whales both regularly dived for 48-68 minutes on deep dives (>800 m [>2,625 ft]).

Heading Variance

Sowerby's beaked whales surfacing in the Gully were reported to have no apparent orientation, and would change orientation up to 180° between surfacing (Hooker and Baird, 1999a).

Speed

Dive rates averaged 1 m/s (3.3 ft/s) or 3.6 km/hr (2.2 mi/hr) (Hooker and Baird, 1999b). A mean surface speed of 5 km/hr (3 mi/hr) was reported by (Kastelein and Gerrits, 1991).

Habitat

The minimum sea depth in which beaked whales were found in the Gulf of Mexico was 253 m (830 ft) (Davis et al., 1998). In the Gully in Canada, Sowerby's beaked whales were found in water ranging from 550 to 1,500 m (1,804 to 4,921 ft) in depth (Hooker and Baird, 1999a). Blainsville's beaked whales (*M. densirostris*) were found in water depths of 136-1,319 m (446-4,327 ft) in the Bahamas, and were found most often in areas with a high bathymetric slope (MacLeod and Zuur, 2005). Mesoplodons were found in waters from 700 to >1,800 m (2,297 to >5,906 ft) off Scotland and the Faroe Islands (Weir, 2000) and between 680 and 1,933 m (2,231 and 6,342 ft) in the Gulf of Mexico (Davis et al., 1998).

Baird et al. (2006) reported that Blainsville's beaked whales off Hawaii were found in waters from 633 to 2,050 m (2,077 to 9,726 ft) deep (mean=1,119) while Cuvier's beaked whales were found in waters from 1,381 to 3,655 m (4,531 to 11,992 ft) deep (mean=2,131).

Group Size

Mesoplodon stejnegeri in Alaska had pod sizes between 5 and 15 animals (Loughlin, 1982). Sowerby's beaked whale in the Gully in Canada had group sizes between 3 and

10 (Hooker and Baird, 1999a). Dense-beaked whales off the Canary Islands had group sizes ranging between 2 and 9 with a mean size of 3.44 whales (Ritter and Brederlau, 1999). Sightings of Longman's beaked whale in the western Indian Ocean found group sizes between 1 and 40 with a mean size of 7.2 whales (Anderson et al., 2006).

5.2.3.14 Dwarf and Pygmy Sperm Whales (Kogia spp.)

The data on dwarf and pygmy sperm whales are rare. Data for these two similar species have been combined.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Kogia spp.	1/2	75º	200/1,000	5/12	30	1/11	Norm.	117/reflect

Surface Time

Observations of *Kogia* off Hawaii found that they remained at the surface for up to a "few" minutes then dove (Baird, 2005).

Dive Depth

Kogia were found in the Gulf of Mexico in waters less than 1,000 m (3,281 ft) along the upper continental slope (Baumgartner et al., 2001). The dive limits of 200-1,000 m (656-3,281 ft) were chosen based on similar species diving deeply to feed and within the physical constraints of the environment. It should be noted that *Kogia* have been seen in waters almost 2,000 m (6,562 ft) deep (Davis et al., 1998) but they may not be diving to the bottom.

Dive Time

Maximum dive time reported for *Kogia* is 12 minutes (Hohn et al., 1995). A rehabilitated pygmy sperm whale made long dives from 2 to 11 minutes in length at night and shorter dives during the day (Scott et al., 2001).

Speed

Tracking of a rehabilitated pygmy sperm whale found that speeds range from 0 to 6 knots (11 km/hr [7 mi/hr]) with a mean value of 3 knots (Scott et al., 2001).

Habitat

Kogia were found in the Gulf of Mexico at a minimum depth of 176 m (577 ft) (Davis et al., 1998). They were found off Hawaii in waters between 450 and 3,200 m (1,476 and 10,499 ft) deep, with a mean of 1,425 m (4,675 ft) (Baird, 2005). *Kogia* in the Philippines were found in waters from 117 to 3,744 m (384 to 12,284 ft) in depth (Dolar and Perrin, 2003).

Group Size

Group sizes off Hawaii ranged between 1 and 6 animals (Baird, 2005) and group sizes in the Gulf of Mexico range between 1 and 3 (Mullin et al., 2004).

5.2.3.15 Lagenorhynchus Species

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)
Lags	1/1	75º	25/125	1/3	30	2/9	Norm.

Surface Time

Surface times for tagged white-sided dolphins were less than one minute (Mate et al., 1994).

Dive Depth

No direct data on dive depth are available for any of the *Lagenorhynchus*. However, in the Atlantic they feed on herring and in the Pacific they feed on squid and mesopelagic fishes. For Atlantic white-sided dolphin a maximum dive depth of 125 m (410 ft) is used since this covers the depth range of herring; it is slightly shallower than the other dolphin species due to the *Lagenorhynchus*' short dive time.

Dive Time

Maximum dive time for a tagged white-sided dolphin was 4 minutes, although the mean time was <1 minute (Mate et al., 1994). Peale's dolphin (*L. australis*) dove from 1 to 130 s (de Haro and Iniguez, 1997).

Speed

The mean minimum speed of 5.7 km/hr (3.5 mi/hr) was estimated by the straight line distance between satellite tag locations, which is almost certainly an underestimate of real-world swimming speeds (Mate et al., 1994). The maximum "minimum speed" was 14.22 km/hr (8.83 mi/hr). A white-sided dolphin in captivity swam between 1.5 and 3.5 m/s (5 and 11.5 ft/s) (5.4 and 12.6 km/hr [3.4 and 7.8 mi/hr) (Curren et al., 1994). Theodolite tracking of dusky dolphins (*L. obscurus*) produced mean speeds between 3.68 and 6.08 km/hr (2.4 and 3.8 mi/hr) with 10^{th} and 90^{th} percentiles of ~2 and ~9 km/hr (~ 1 and ~ 6 mi/hr) (Yin, 1999).

Group Size

The mean size of Atlantic white-sided dolphin groups was 52 (Weinrich et al., 2001). The mean group size of Pacific white-sided dolphins was 30.8 (Barlow, 1995). In Southeast Alaska, the group size was extremely variable, ranging from 1 to 500 animals, with an overall mean of 35.6 animals (Dahlheim and Towell, 1994).

5.2.3.16 Fraser's Dolphin

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Fraser's Dolphin	1/1	75º	10/700	1/6	30	2/9	Norm.	100/reflect

Dive Depth

Fraser's dolphins dive to about 600-700 m (1,969-2,297 ft) to feed which is much deeper than spinner dolphins (Dolar et al., 2003). Numerous records indicated that the primary prey of Fraser's dolphins is found at great depth (Caldwell et al., 1976; Miyazaki and Wada, 1978; Robison and Craddock, 1983), although there has been at least one report of near-surface feeding (Watkins et al., 1994). All other behavioral parameters are taken from *Stenella* species since there are no direct data for Fraser's dolphin. The dive time has been increased to six minutes to account for the deeper dives.

Group Size

A single group of Fraser's dolphins was seen off the Pacific Coast of Costa Rica and had a group size of 158 (May-Collado et al., 2005).

5.2.3.17 Small Beaked Whales (Mesoplodon, Ziphius, Tasmacetus)

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Beaked Whales	1/7	75º	1,000/1,453 (60) 100/800 (40)	48/68 12/30	30/300 (50) 90/300 (50)	3/6	Norm.	253/reflect

Surface Time

Surface times in Arnoux's beaked whales ranged from 1.2 to 6.8 minutes (Hobson and Martin, 1996). Sowerby's beaked whales had surface times of 1-2 minutes, during which they would blow 6-8 times (Hooker and Baird, 1999a).

Dive Depth

The minimum and maximum dive depth measured for a beaked whale was 120 and 1,453 m (394 and 4,767 ft) respectively (Hooker and Baird, 1999b). Cuvier's beaked whales tagged off the Canary Islands had foraging dives between 824 and 1,267 m (2,703 and 4,157 ft) while Blainsville's beaked whales dove to depths between 655 and 975 m (2,149 and 3,199 ft) (Johnson et al., 2004).

Northern Bottlenose whales performed shallow dives with a range of 41-332 m (135-1,089 ft) (n=33), while deep dives ranged from 493 to 1,453 m (1,617 to 4,767 ft) (n=23). Dive depth and dive duration were strongly correlated (Hooker and Baird, 1999b).

Blainsville's beaked whales in Hawaii performed dives to mid-water depth (100-600 m [328-1,969 ft]) approximately six times more frequently than at night. Dives deeper than 800 m (2,625 ft) had no diurnal difference (Baird et al., 2008).

Dive Time

The minimum and maximum dive time measured was 16 and 70.5 minutes respectively (Hooker and Baird, 1999b). Sowerby's beaked whales had dives between 12 and (at least) 28 minutes in the Gully in Canada (Hooker and Baird, 1999a). Arnoux's beaked whale had modal dive times between 35-65 minutes (mean=46.4 min, SD=13.1) with a maximum dive time of at least 70 minutes (Hobson and Martin, 1996). Tagging results with *Ziphius* had one animal diving for 50 minutes (Johnson et al., 2004). *Mesoplodon stejnegeri* were observed to dive for 10-15 minutes in Alaska (Loughlin, 1982).

Blainsville's beaked whales and Cuvier's beaked whales both regularly dove for 48-68 minutes on deep dives (>800 m [>2,625 ft]).

Heading Variance

Sowerby's beaked whales surfacing in the Gully were reported to have no apparent orientation, and would change orientation up to 180° between surfacing (Hooker and Baird, 1999a).

Speed

Dive rates averaged 1 m/s (3.3 ft) or 3.6 km/hr (2.2 mi/hr) (Hooker and Baird, 1999b). A mean surface speed of 5 km/hr (3.1 mi/hr) was reported by Kastelein and Gerrits (1991).

Habitat

The minimum sea depth in which beaked whales were found in the Gulf of Mexico was 253 m (830 ft) (Davis et al., 1998). Sowerby's beaked whales in the Gully in Canada were found in water ranging from 550 to 1,500 m (1,804 to 4,921 ft) in depth (Hooker and Baird, 1999a). Blainsville's beaked whales (*M. densirostris*) were found in water depths of 136-1,319 m (446-4,327 ft) in the Bahamas, and were found most often in areas with a high bathymetric slope (MacLeod and Zuur, 2005). *Mesoplodons* were found in waters from 700 to >1,800 m (2,297 to 5,906 ft) off Scotland and the Faroe Islands (Weir, 2000) and between 680 and 1,933 m (2,231 and 6,342 ft) in the Gulf of Mexico (Davis et al., 1998).

Baird et al. (2006) reported that Blainsville's beaked whales off Hawaii were found in waters from 633 to 2,050 m (2,077 to 6,726 ft) deep (mean=1,119 m [3,671 ft]) while Cuvier's beaked whales were found in waters from 1,381 to 3,655 m (4,531 to 11,992 ft) deep (mean=2,131 m [6,991 ft]).

Group Size

Mesoplodon stejnegeri in Alaska had pod sizes between 5 and 15 animals (Loughlin, 1982). Sowerby's beaked whale in the Gully in Canada had group sizes between 3 and 10 (Hooker and Baird, 1999a). Dense-beaked whales off the Canary Islands had group sizes ranging between 2 and 9 with a mean size of 3.44 whales (Ritter and Brederlau, 1999). Sightings of Longman's beaked whale in the western Indian Ocean found group sizes between 1 and 40, with a mean size of 7.2 whales (Anderson et al., 2006).

5.2.3.18 Killer Whale

There is a remarkable paucity of quantitative data available for killer whales considering their coastal habitat and popular appeal. Nevertheless, most data from "blackfish" were used to model orca with the exception of dive depth. The different feeding ecology of these species makes very deep dives apparently unnecessary. When additional data allow, separate animats need to be developed for "resident" and "transient" killer whales.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Killer Whale	1/1	75º	10/180	1/10	30	3/12	Norm.	25/reflect

Dive Depth

Killer whales feeding on herring were observed to dive to 180 m (591 ft) (Nøttestad et al., 2002). Killer whales are found in at least two "races", transients and residents. Transients feed primarily on marine mammals whereas residents feed primarily on fish. Residents were reported to dive to the bottom (173 m [568 ft]) (Baird, 1994). Baird (1994) also reported that while residents dive deeper than transients, the transients spent a far greater amount of time in deeper water. Individual resident killer whales in the Pacific northwest had maximum dive depths ranging between 24 and 264 m (79 and 866 ft) with a group mean maximum depth of 140.8 m (462 ft) (SD=61.8, n=34) (Baird et al., 1995). The distribution of dive depths reported by Baird et al. (2005) was strongly skewed toward shallow values.

Dive Time

The daytime dive times for males were 2.79 minutes, significantly longer than the 2.09 minute dive times for females (Baird et al., 2005).

Speed

Uncalibrated swim speed data were presented by Baird et al. (2005). Killer whales chasing minke whales had prolonged speeds of 15-30 km/hr (9-19 mi/hr) (Ford et al., 2005) although these speeds are probably obtained only during predation. A shore-based study of southern resident killer whales in Washington State had a mean speed of 9.5 km/hr (5.9 mi/hr) with a mean range of 4.7-16.1 km/hr (2.9-10 mi/hr) (Kriete, 2002). The mean speed of control animals was approximately 5.3 km/hr (3.3 mi/hr), measured during a study of the response of killer whales to vessels (Williams et al., 2002). A similar study reported a mean speed of 6.64 km/hr (4.13 mi/hr) without vessels and 6.478 km/hr (4.03 mi/hr) in the presence of vessels (Bain et al., 2006). Taken together, these three studies produced a speed range of 3-12 km/hr (1.9-7.5 mi/hr) for use in AIM.

Habitat

Killer whales are known to occur in very shallow water (e.g., rubbing beaches) as well as cross open ocean basins. However, they are usually coastal and most often found in temperate waters.

Killer whales in the Gulf of California were seen in groups of 2-15 whales with a mean of 8.5 and a SD of 9.19 (n=2) (Silber et al., 1994). Off the Pacific Coast of Costa Rica, the mean group size was 3.51 (SD=2.99, n=7) (May-Collado et al., 2005).

5.2.3.19 Harbor Porpoise

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Harbor Porpoise	1/1	17/31	1/10 (35) 10/40 (45) 40/100 (15) 100/230 (5)	1/4	30	2/7	Norm.	100-1,000/ reflect

Surface Time

Mean surface time was reported as 3.9 s (Otani, 2000).

Dive Depth

Maximum observed dive depth for a free-ranging harbor porpoise was 64.7 m (212 ft) (Otani, 2000). However, the same study reported that >90 percent of dives were less than 10 m (33 ft). Another TDR study with seven animals tagged had dive depths that ranged from a mean of 14 +/- 16 m (46 +/- 52 ft) to 41 +/- 32 m (135 +/- 105 ft) while the mean for all animals tagged was 25 +/- 30 m (82 +/- 98 ft) (Westgate et al., 1995). One large female made a very deep dive to 226 m (741 ft) although dives this deep were infrequent.

Dive Time

Maximum observed dive time for a free-ranging harbor porpoise was 193 s (Otani, 2000) although most dives were less than one minute in length. The mean dive duration of seven animals in the Bay of Fundy was 65 +/-33 s (Westgate et al., 1995).

Speed

Mean descent speed was 2.9 km/hr (1.8 mi/hr) with a maximum descent speed of 15.5 km/hr (9.6 mi/hr). Ascent speeds were similar, with a mean of 3.24 km/hr (2 mi/hr) and a maximum of 14.5 km/hr (9 mi/hr) (Otani, 2000). TDR tagged animals moved at least 51 km (32 mi) in a 24 hr period (2.125 km/hr [1.3 mi/hr]) (Westgate et al., 1995). A captive harbor porpoise swam between 3.6-7.2 km/hr (2.2-4.5 mi/hr) (Curren et al., 1994). A speed range of 2-7 km/hr (1.2-4.3 mi/hr) was used in AIM to represent the harbor porpoise speed.

Group Size

The mean group size of harbor porpoise off California was 5.0 individuals (n=31) (Barlow, 1995).

5.2.3.20 Sperm Whale

There are indications of diurnal differences in diving behavior (Aoki et al., 2007). There is also evidence of large-scale variability between environments. Therefore, these parameters should be considered generalized and warrant location specific refinement.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Sperm Whale	8/11	90/75º	600/1,400 (90) 200/600 (10)	18/65	20	1/10	Norm.	200/reflect
Atlantic Ocean Model Parameters								
Atlantic Sperm Whale	5/9	90/75º	600/1,000	35/65	30/300 (50) 90/300 (50)	1/8	Norm.	200/reflect

Surface Time

Male sperm whales in New Zealand had a mean duration on the surface of 9.1 minutes, with a range of 2-19 minutes (Jaquet et al., 2000). The distribution of surface times was non-normal, with 68 percent of the surface times falling in between 8 and 11 minutes. These values were used for AIM modeling.

Surfacing and Dive Angles

Surfacing angles of 90° and diving angles between 60° and 90° have been reported (Miller et al., 2004).

Dive Depth

The maximum, accurately measured, sperm whale dive depth was 1,330 m (4,364 ft) (Watkins et al., 2002). Foraging dives typically begin at depths of 300 m (984 ft) (Papastavrou et al., 1989). Digital acoustic recording tag (DTAG) data from the Gulf of Mexico show that most foraging dives were between the depths of 400-800 m (1,312-2,625 ft), with occasional dives between 900 and 1,000 m (2,953 and 3,281 ft) (Jochens et al., 2008, Figure 5.2.2). Sperm whale diving is not uniform. As an example, data from a paper on sperm whale diving reported different dive types (Amano and Yoshioka, 2003). The AIM can now accommodate these different dive types at different frequencies of use.

		Depth		Time	
Type of Dive	N	AIM min	AIM max	AIM min	AIM max
Dives w/active bottom period	65	606	1082	33.17	41.63
Dives w/o active bottom period	4	417	567	31.29	33.71
V shaped dives	3	213	353	12.77	20.83
Total	72				

Dive depths have also been shown to have diel variation in some areas while others do not show this variation (Aoki et al., 2007). These differences have been attributed to the behavior of the prey species. Tagged whales off California changed their dive patterns in response to changes in the depth of tagged squid (Davis et al., 2007).

Male sperm whales foraging in high latitude waters dove to a maximum depth of 1,860 m (6,102 ft), but the median dive depth was only 175 m (574 ft) (Teloni et al., 2008). In the Atlantic, maximum dive depths ranged from 639 to 934 m (2,096 to 3,064 ft) (Palka and Johnson, 2007).

Area	Average Duration (min)				
	Foraging Dive			Inter-Dive Interval	Surface Interval
	Total	Descent	Ascent		
North Atlantic	44.6	24.4	20.2	7.1	70.0
Gulf of Mexico	44.7	22.2	22.4	8.2	63.7
Mediterranean	40.3	24.4	19.3	9.7	57.5
Area	**Average Depth (m)**				
	Maximum Depth of Foraging Dives			**Inter-Dive Interval**	**Surface Interval**
North Atlantic	933.9			1.15	5.6
Gulf of Mexico	638.7			0.45	4.6
Mediterranean	797.3			0.34	4.9

Sperm whales showed diel variability off Ogasawara, Japan. Whales dove deeper during the day (mean=853 +/- 130 m [2,799 +/- 427 ft]) than at night (mean=469 +/- 122 m [1,539 +/- 400 ft]) (Aoki et al., 2007). However, off the Kumano Coast, there was not a large difference in depths (561 versus 646 m [1,841 versus 2,119 ft]).

Dive Time

Sperm whale dive times average 44.4 minutes in duration and range from 18.2 to 65.3 minutes (Watkins et al., 2002). In the Gulf of Mexico, the modal dive time is about 55 minutes (Jochens et al., 2008, Figure 4.4.3). Dive times in the Atlantic averaged 40-45 minutes (Palka and Johnson, 2007).

Dive times off Ogasawara, Japan had an average of 40.1 minutes (SD=4.5) during the day and a mean of 32.3 minutes (SD=5.3) at night (Aoki et al., 2007). Off the Kumano Coast of Japan, they had intermediate values of 36.1 minutes (SD=3.7) during the day and 34.1 (SD=7) minutes at night.

Heading Variance

Whales in the Gulf of Mexico tend to follow bathymetric contours (Jochens et al., 2008). Relative angles between direction of movements and direction of contours have been calculated and transformed so that 0 shows alignment with the orientation of the contour, -90 would be moving directly offshore, and +90 would indicate a movement directly inshore (Jochens et al., 2008, Figure 4.4.5).

Speed

Sperm whales are typically slow or motionless on the surface. Mean surface speeds of 1.25 km/hr (0.78 mi/hr) were reported by Jaquet et al. (2000) and 3.42 km/hr (2.13 mi/hr) (Whitehead et al., 1989). Their mean dive rate ranges from 5.22 to 10.08 km/hr (3.24 to 6.26 mi/hr) with a mean of 7.32 km/hr (4.55 mi/hr) (Lockyer, 1997). In Norway, horizontal swimming speeds varied between 0.72 and 9.36 km/hr (0.45 and 5.8 mi/hr) (Wahlberg, 2002). Sperm whales in the Atlantic Ocean swam at speeds between 2.6 and 3.5 km/hr (1.6 and 2.2 mi/hr) (Jaquet and Whitehead, 1999; Watkins et al., 1999).

Mean speeds in the Gulf of Mexico were 3.3 km/hr (2.1 mi/hr) (Jochens et al., 2008). Based on these data, a minimum speed of 1 km/hr (0.6 mi/hr) and a maximum speed of 8 km/hr (5 mi/hr) was set for sperm whales specified with a normal distribution so that mean speeds would be about 4 km/hr (2.5 mi/hr).

Off Ogasawara Japan, sperm whales swam faster during the day (mean=2.0 m/s [6.6 ft/s], SD=0.3) than during the night (mean=1.5 m/s [5 ft/s], SD=0.3).

Habitat

Sperm whales are found almost everywhere, but they are usually in water deeper than 480 m (1,575 ft) (Davis et al., 1998). However, there have been sightings of animals in shallow water (40-100 m [131-328 ft]) (Whitehead et al., 1992; Scott and Sadove, 1997). In the Gulf of California there was no relationship between depth or bathymetric slope and abundance and animals were seen in water as shallow as 100 m (328 ft) (Jaquet and Gendron, 2002). Based on these reports, a compromise value of 200 m (656 ft) was used as the shallow water limit for sperm whales.

Group Size

Social, female-centered groups of sperm whales in the Pacific have “typical” group sizes of 25-30 animals, based on the more precise measurements in (Coakes and Whitehead, 2004), although less precise estimates are as high as 53 whales in a group.

5.2.3.21 Stenella: Spinner, Spotted and Striped Dolphins

Most *Stenella* species have strong diurnal variation in their behavior. Separate daytime and nighttime animats was built for this species by programming two dive behaviors. The relative proportion of these dive types can be scaled by the local photoperiod with the AIM weighting parameter.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Stenella	1/1	75º	Day: 5/25 (50) Night: 10/400 (10) Night: 10/100 (40)	1/4	30	2/9	Norm.	10/reflect

Dive Depth

Spinner dolphins feed during the night and rest inshore during the daytime. At night they dive to about 400 m (1,312 ft) to feed (Dolar et al., 2003).

Pantropical spotted dolphins off Hawaii also dive deeper at night than during the day. The daytime depth had a mean of 12.8 m (42 ft), with a maximum of 122 m (400 ft), whereas the night-time mean was 57 m (187 ft), with a maximum of 213 m (699 ft) (Baird et al., 2001).

Spinner dolphins off Hawaii typically track and forage upon the mesopelagic boundary layer as it migrates both vertically and horizontally at night. It appears that dolphins have to dive deeply only at the very beginning and end of the migration (Benoit-Bird and Au, 2003) foraging mostly at moderate depths.

Therefore, 10 percent of the dives were set to be deep, 40 percent of the dives were "typical" foraging depths, with a maximum of 150 m (492 ft), and 50 percent of the dives were set to represent the daytime resting behavior ranging between 5 and 25 m (16 and 82 ft).

Dive Time

A single spotted dolphin has dive times ranging between 1 and 204 s (Leatherwood and Ljungblad, 1979). Pantropical spotted dolphins off Hawaii had a mean dive duration of 1.95 minutes (SD=0.92) (Baird et al., 2001). An Atlantic spotted dolphin tagged with a satellite linked TDR had a maximum dive time of 3.5 minutes (Davis et al., 1996). A four minute dive time maximum was used for modeling purposes in AIM.

Speed

The mean speed of striped dolphins in the Mediterranean was estimated at 6.1 knots (11 km/hr [6.8 mi/hr]) and burst to 32 knots were observed (Archer and Perrin, 1999). A maximum speed of 20 km/hr (12 mi/hr) was chosen as a typical (non-burst) maximum speed. A tagged spotted dolphin was tracked at estimated average speeds of 2.3-10.7 knots with bursts exceeding 12 knots (Leatherwood and Ljungblad, 1979). The estimated burst speed of spotted dolphins in the Eastern Tropical Pacific was 21.6 km/hr (13.4 mi/hr) for adults and 10.8 km/hr (6.7 mi/hr) for neonates. The estimated long-term top speed is 9 km/hr (5.6 mi/hr) for adults and 3.6 km/hr (2.2 mi/hr) for neonates (Edwards, 2006). The Edwards (2006) paper also summarized speed estimates and duration for a number of species. Therefore their estimate of 9 km/hr (5.6 mi/h) was used for long-term movements, as modeled in AIM.

Habitat

In the Gulf of Mexico spinner dolphins were seen in water deeper than 526 m (1,726 ft), striped dolphins were seen in water deeper than 570 m (1,870 ft), and spotted dolphins were seen in water deeper than 102 m (335 ft) (Davis et al., 1998). Spinner dolphins in Hawaii are known to move into shallow bays during the day (Norris and Dohl, 1980).

Group Size

Group size estimates were summarized, and the majority of striped dolphin groups were less than 500 animals. The mean of the smaller groups was 101 animals (Archer and Perrin, 1999). Spotted dolphins off Costa Rica had group sizes between 1 and 50 (mean=10.16, SD=9.61) (May-Collado and Ramirez, 2005).

Summary of Gulf of Mexico Data (Source: Mullin et al., 2004)

Species	Min Group Size	Max Group Size	Mean	SE	N
Pantropical spotted dolphin	5	210	49.0	4.5	47
Atlantic spotted dolphin	5	48	22.4	3.9	12
Striped dolphin	7	150	46.3	16.0	8
Spinner dolphin	48	200	91.3	36.4	4
Clymene dolphin	9	168	59	19.5	7

Clymene dolphins off Costa Rica had a mean group size of 76.1 (SE=11, n=109) (Fertl et al., 2003).

Summary of Pacific Costa Rica Data (May-Collado et al., 2005)

Species	Mean	SD
Pantropical spotted dolphin	29.38	58.28
Striped dolphin	48.9	43.05
Spinner dolphin	100.59	107.7

5.2.3.22 Bottlenose Dolphin

In many environments, there can be coastal and pelagic stocks of bottlenose dolphins. This is certainly the case off the east coast of the U.S., however defining the range of offshore form is difficult (Wells et al., 1999). Regardless of the genetic differences that may exist between these two forms, they frequently occur at different densities and are split into two animat categories.

Model Parameters

	Min/Max Surface Time (min)	Surface/Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/hr)	Speed Distribution (α,β)	Depth Limit/Reaction Angle
Bottlenose (Coastal)	1/1	75º	15/98	1/3	30	2/16	Norm.	10/reflect
Bottlenose (Pelagic)	1/1	75º	6/50 (80) 50/100 (5) 100/250 (5) 250/450 (10)	1/2 2/3 3/4 5/6	30/300 (45) 90/90 (45) 90/90 (10)	2/16	Norm.	101/1,226 reflect

Dive Depth

An early maximum recorded dive depth for wild bottlenose dolphins is 200 m (656 ft) (Kooyman and Andersen, 1969). More recently, offshore bottlenose dolphins were reported to dive to depths greater than 450 m (1,476 ft) (Klatsky et al., 2007).

A satellite tagged dolphin in Tampa Bay, Florida had a maximum dive depth of 98 m (322 ft) (Mate et al., 1995). This value was used as the maximum dive depth for the coastal form of bottlenose.

Dive Time

Measured surface times ranged from 38 s to 1.2 minutes (Lockyer and Morris, 1986, 1987; Mate et al., 1995). Dive depths for a juvenile bottlenose had a mean value of 55.3 s although the distribution was skewed toward shorter dives (Lockyer and Morris, 1987). However, pelagic bottlenose dolphins were observed to dive for periods longer than five minutes (Klatsky et al., 2007).

Speed

Bottlenose dolphins were observed to swim for extended periods at speeds of 4-20 km/hr (2.5-12.4 mi/hr), although they could burst (for about 20 s) at up to 54 km/hr (34 mi/hr) (Lockyer and Morris, 1987). Dolphins in the Sado Estuary, Portugal had a mean speed of 4.3 km/hr (2.7 mi/hr) and maximum speed of 11.2 km/hr (7 mi/hr) (Harzen, 2002). A more recent analysis found that maximum speed of wild dolphins was 20.5 km/hr (12.7 mi/hr), although trained animals could double this speed when preparing to leap (Rohr et al., 2002). Maximum speeds of wild dolphins in France was 4.8 m/s (15.7 ft/s), with an average speed (relative to water) of 7.9 km/hr (4.9 mi/hr) (Ridoux et al., 1997). Bottlenose dolphins off Argentina swam much faster (14 km/hr [9.7 mi/hr]) when in water >10 m (>33 ft) than while in shallow water (5.8 km/hr [3.6 mi/hr]) (Würsig and Würsig, 1979).

Habitat

In the Gulf of Mexico, bottlenose dolphins where observed in water depths between 101 and 1,226 m (331 and 4,022 ft) (Davis et al., 1998). However tagged animals have been observed to swim into water 5,000 m (16,404 ft) deep (Wells et al., 1999).

Group Size

Bottlenose dolphins in the Gulf of California were seen in groups of 1-60 dolphins with a mean group size of 10.1 (Silber et al., 1994). In the Gulf of Mexico they were seen in groups of 1-68 individuals (mean=14.5, SE=1.5, n=83) (Mullin et al., 2004). Off the Pacific Coast of Costa Rica the mean group size was 21.5 (SD=33.73, n=176) (May-Collado et al., 2005).

5.2.3.23 Hooded Seal (Cystophora cristata)

Model parameters

	Min/Max Surface Time (min)	Surface/ Dive Angle	Dive Depth (m) Min/max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle/time)	Min/Max Speed (km/h)	Speed distribution	Depth limit /reaction angle
Hooded seal	0.5/2.7 0.5/2.7		100/600 (70) 15/52 (17) 100/1016(13)	5/25 1/5		1/4		

Surface Time

Harbor seals dive continuously while at sea, being submerged for 90.7 ±. 0.8% of the time (Folkow and Blix, 1999).

Dive Depth

Dives to depths of 100-600 m accounted for >70% of dives whereas dives to less than 52 m accounted for about 17% of dives (Folkow and Blix, 1999). The maximum recorded dive depth was 1016 m, the limit of the recording equipment (Folkow and Blix, 1999). The average dive depth of all dive types reported by Kovacs et al. (1996) was 39 ± 17 m (Schreer et al., 2001).

These two reports disagree strongly suggesting a seasonal difference in behavior between the two populations.

Dive Time

Dives of 5-15 min durations accounted for 47.1% of dives and dives of 15-25 min durations accounted for 30.6% of dives, for an average duration ± SE of 14.3 ± 0.1 min (Folkow and Blix, 1999). The average (± SD) dive duration of all dive types reported by Kovacs et al. (1996) was 5.5 ± 3.9 m (Schreer et al., 2001).

Habitat

Pupping season is March/April, molting season is July. After pupping or molting on the sea ice near Jan Mayen, seals disperse to distant waters off the Faroe Islands, south of Bear Island, or the Irminger Sea (Folkow and Blix, 1999).

Group Size

Hooded seals are solitary (Reeves et al., 2002).

5.2.3.24 Harbor Seal (Phoca vitulina)

Model parameters

	Min/Max Surface Time (min)	Surface / Dive Angle	Dive Depth (m) Min/max (Percentage)	Min Max Dive Time (min)	Heading Variance (angle time)	Min/Max Speed (km/h)	Speed distribution	Depth limit /reaction angle
Harbor seal	0.33/1 0.33/1 0.33/1 1/4	30/70	0/5(40) 5/20(15) 50/150(5) -1/5(40)	0.5/2 0.5/2 4/7 1/4		1/4		

Surface Time

Harbor seals dive in bouts. Adult females spend 44.6 ± 4.68% of their time hauled out on land and 55.4 ± 4.68% of time at sea. While at sea, they spend 8.9 ± 2.89% of time diving (Bowen et al., 1999). Five different dive types, surface intervals: 42.6 ± 23.5 s, 43.8 ± 60.7, 40.2 ± 31.0 s, 38.6 ± 34.8 s, 44.8 ± 31.9 s (Lesage et al., 1999)

Dive Depth

~50% of diving shallower than 40 m, 95% of diving shallower than 250 m (Gjertz et al., 2001). Most dives (40-80%) were < 20 m, though dives from 50 to 150 m were not uncommon and dives to 508 m were recorded (Hastings et al., 2004). For 20 lactating females: mean dive depth 11.3 ± 0.83 m (Bowen et al., 1999). Five different dive types: 19.6 ± 5.8 m, 5.8 ± 2.8 m, 7.8 ± 2.7 m, 7.9 ± 2.7 m, and 12.2 ± 7.2 m (Lesage et al., 1999). Harbor seals in Monterey Bay had an absolute maximum dive depth of 481 m while median depths were between 5 and 100 m (Eguchi and Harvey, 2005).

Dive Time

Mean dive durations for individual seals (14 females and 11 males) ranged from 46 s to 2.9 min with a high proportion of dives being less than 2 min; max duration was 31 min (Ries et al., 1997). ~50% of dives lasted 2-4 min, 90% lasted less than 7 min, and 97% less than 10 min (Gjertz et al., 2001). Most dives were < 4 min in duration (Hastings et al., 2004). For 20 lactating females: mean dive duration 1.6 ± 0.09 min (Bowen et al., 1999). Five different dive types: 135.7 ± 37.5 s, 40.1 ± 29.8 s, 122.4 ± 50.9 s, 142.3 ± 52.9 s, 167.9 ± 80.1 s (Lesage et al., 1999).

Speed

For 20 lactating females: mean ascent rate 0.6 ± 0.03 m/s; mean descent rate 0.6 ± 0.03 m/s (Bowen et al., 1999). Five different dive types: median swim speed (bottom) 1.00 ± 0.47 m/s, 0.47 ± 0.56 m/s, 1.21 ± 0.44 m/s, 0.68 ± 0.40 m/s, 0.15 ± 0.25 m/s (Lesage et al., 1999). Angle of ascent (deg): 70.0 ± 27.8, 59.0 ± 33.6, 48.0 ± 29.3, 31.2 ± 26.8, 75.9 ±24.1 (Lesage et al., 1999). Angle of descent (deg): 63.6 ± 29.8, 59.8 ± 34.4, 32.1 ± 28.9, 64.0 ± 28.6, 71.8 ±27.4 (Lesage et al., 1999).

Habitat

Animals may move between different haul-out sites or between favored haul-out sites and foraging areas, but these are usually less than 50 km apart (Gjertz et al., 2001). Harbor seals are generally considered to feed close to the sea floor at depths between 4-200 m (Gjertz et al., 2001). Five different dive types have been identified (Lesage et al., 1999).

Group Size

Harbor seals are solitary at sea (Reeves et al., 2002).

6 Acoustic Criteria or Thresholds

6.1 Injury Criteria

Two sets of criteria were used to estimate acoustic exposures for the interpretation of the potential for MMPA incidental harassment Level A (Injury). Since the mid-1990s, NMFS has specified that marine mammals exposed to pulsed sounds, such as those produced by an airgun, at received levels exceeding 180 or 190 dB re 1 µPa RMS for cetaceans and pinnipeds, respectively, were considered injured (**Table 11**). For these criteria, exposure is calculated based on the maximum received level (dB RMS) received by an animal over the entire duration of an activity without any consideration of hearing sensitivity (i.e., no frequency weighting).

Table 11. Historical injury criteria for cetaceans and pinnipeds for pulsed sounds

Group	Level A (Injury) Pressure (unweighted dB re 1 µPa RMS)
Cetaceans	180
Pinnipeds	190

The second set of criteria incorporates more recent data that indicate that injury (permanent threshold shift, PTS) in marine mammals is more closely correlated with sound exposure levels (SEL) that accumulate sound energy over time or very loud, instantaneous peak pressure levels (Southall et al., 2007; **Table 12**).

The cumulative energy criteria should be implemented with M-weighting; i.e., frequency weighting for various groups of marine mammals that de-emphasize frequencies that are near the lower and upper frequency limits of their estimated hearing ranges (Southall et al. 2007; **Figure 13**). The most appropriate interval over which the received acoustic energy should be accumulated is not well studied. However, Southall et al. (2007) has suggested considering noise exposure over 24-hr periods.

The second criteria deal with very loud, instantaneous, impulsive sounds (Southall et al., 2007). The peak pressure criteria define injury to occur at an instantaneous peak pressure of 230 dB re 1 µPa (peak) for cetaceans or 218 dB re 1 µPa (peak) for pinnipeds (**Table 12**). The peak pressure criteria are not frequency weighted.

Table 12. Injury exposure criteria for cetaceans and pinnipeds (Southall et al., 2007)

Marine mammal group	**Sound type**		
	Single pulses	**Multiple pulses**	**Non-pulses**
Low-frequency cetaceans			
Sound exposure level	198 dB re: 1 µPa^2-s (M_{lf})	198 dB re: 1 µPa^2-s (M_{lf})	215 dB re: 1 µPa^2-s (M_{lf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
Mid-frequency cetaceans			
Sound exposure level	198 dB re: 1 µPa^2-s (M_{mf})	198 dB re: 1 µPa^2-s (M_{mf})	215 dB re: 1 µPa^2-s (M_{mf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
High-frequency cetaceans			
Sound exposure level	198 dB re: 1 µPa^2-s (M_{hf})	198 dB re: 1 µPa^2-s (M_{hf})	215 dB re: 1 µPa^2-s (M_{hf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
Pinnipeds (in water)			
Sound exposure level	186 dB re: 1 µPa^2-s (M_{pw})	186 dB re: 1 µPa^2-s (M_{pw})	203 dB re: 1 µPa^2-s (M_{pw})
Sound pressure level	218 dB re: 1 µPa (peak) (flat)	218 dB re: 1 µPa (peak) (flat)	218 dB re: 1 µPa (peak) (flat)

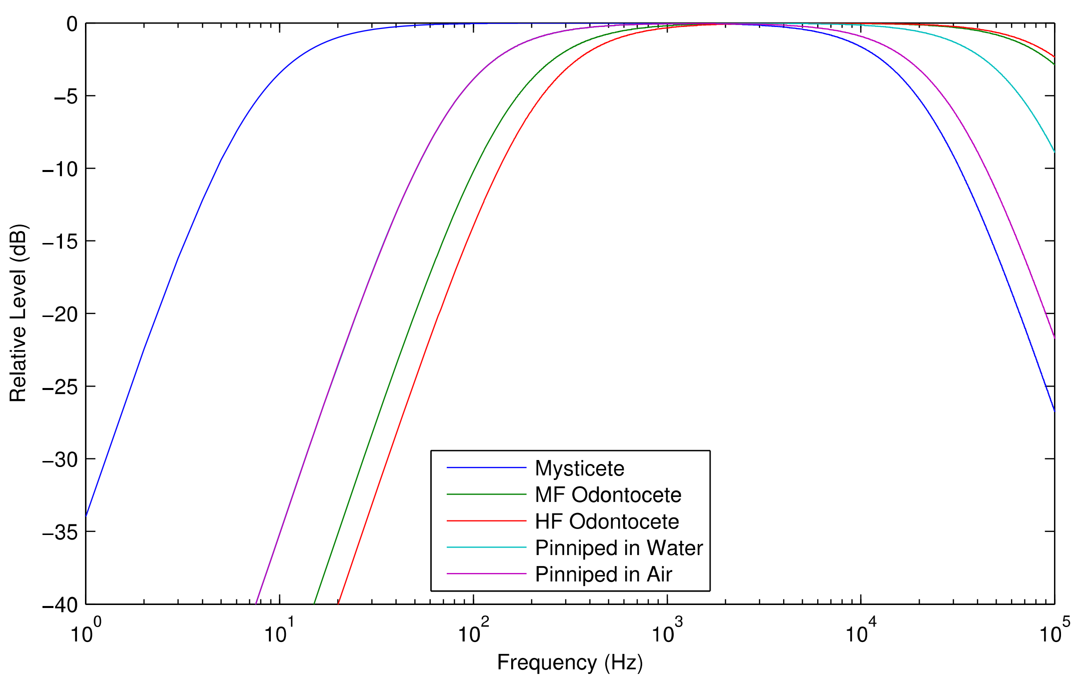

Figure 13. M-weighting curves for marine mammals (Southall et al., 2007)

More recently, the National Oceanic and Atmospheric Administration (NOAA) has distributed draft guidance on underwater acoustic thresholds for onset of PTS (NOAA, 2015). This guidance also includes two criteria, one for SEL and one for peak pressure, specific to functional hearing groups (**Table 13**). As with the Southall et al. (2007) criteria, the peak pressure criteria are not frequency weighted, but the SEL criteria are frequency weighted with functions specific to cetacean (**Figure 14**) and pinniped (**Figure 15**) hearing groups.

Table 23. Summary of draft PTS onset dual metric acoustic threshold levels (NOAA, 2015)

Marine mammal group	**Sound type**	
	Impulsive	**Non-impulsive**
Low-frequency cetaceans		
Sound exposure level	192 dB re: 1 µPa^2-s (M_{lf})	207 dB re: 1 µPa^2-s (M_{lf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
Mid-frequency cetaceans		
Sound exposure level	187 dB re: 1 µPa^2-s (M_{mf})	199 dB re: 1 µPa^2-s (M_{mf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
High-frequency cetaceans		
Sound exposure level	154 dB re: 1 µPa^2-s (M_{hf})	171 dB re: 1 µPa^2-s (M_{hf})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)
Phocid pinnipeds (in water)		
Sound exposure level	186 dB re: 1 µPa^2-s (M_{pw})	201 dB re: 1 µPa^2-s (M_{pw})
Sound pressure level	230 dB re: 1 µPa (peak) (flat)	230 dB re: 1 µPa (peak) (flat)

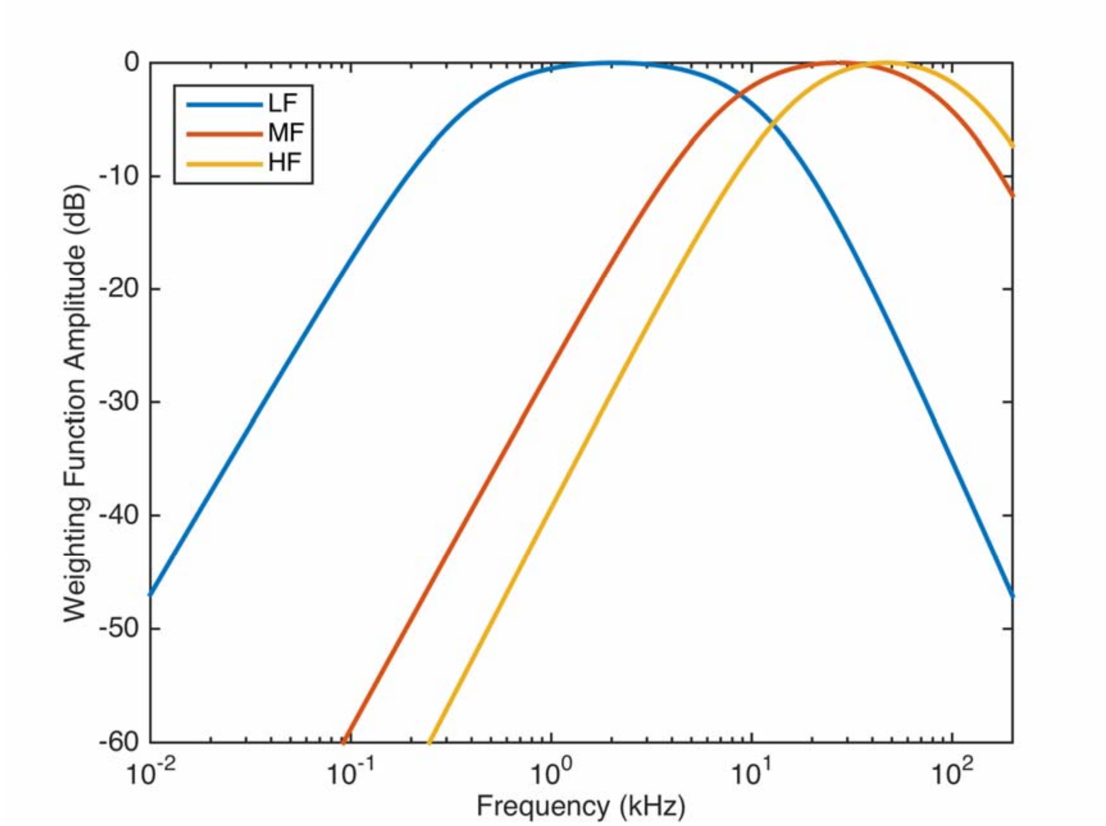

Figure 14. Auditory weighting functions for low-frequency (LF), mid-frequency (MF), and high-frequency (HF) cetaceans (NOAA, 2015)

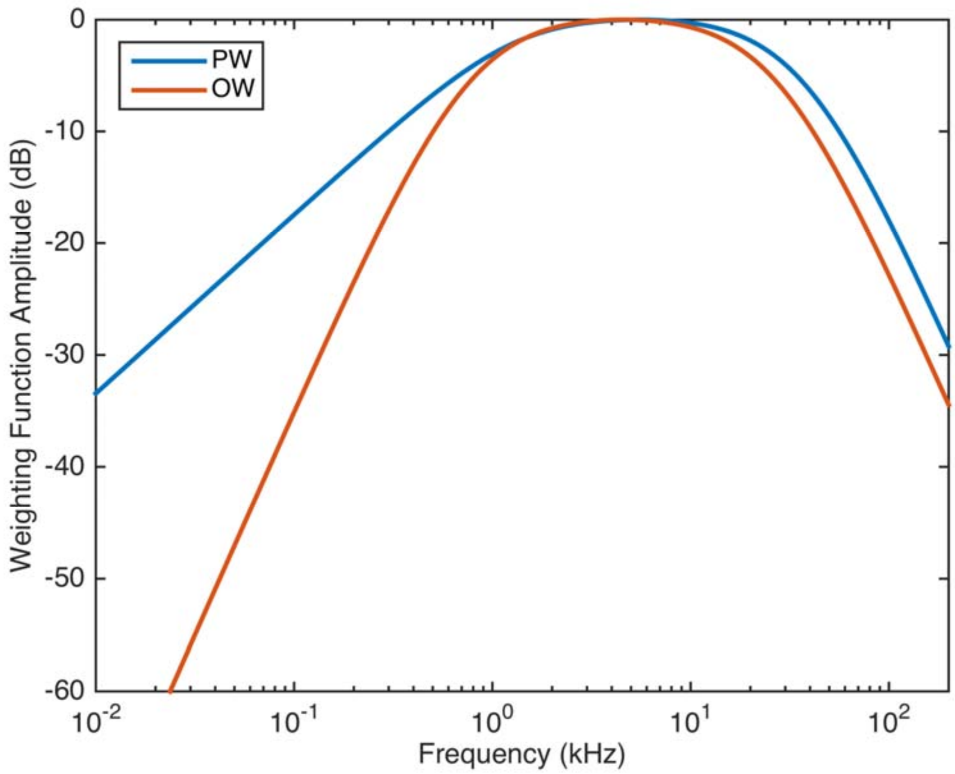

Figure 15. Underwater auditory weighting functions for pinnipeds under water: otariid under water (OW) and phocid under water (OW) (NOAA, 2015)

6.2 Behavioral Disturbance Criteria

The existing NMFS criterion for potential behavioral disturbance to marine mammals from airgun-like sound sources is an unweighted 160 dB re 1 µPa (RMS). It is recognized that many variables other than receive level affect the nature and extent of responses to a particular stimulus (Ellison et al., 2012, Southall et al., 2007); however, there is no mechanism for incorporating those variables into an exposure criterion at this point. The use of the unweighted 160 dB RMS criterion for the MMPA incidental harassment Level B threshold is a reasonable combination of the best current science and historical precedents.

6.3 Acoustic Fields for Exposure Estimates

Separate sound fields were created for unweighted and M-weighted SEL values, as well as the unweighted SPL RMS levels, to determine received levels for animal positions at each modeling time step for these criteria.

7 Acoustic Exposure Modeling

The Acoustic Integration Model© (AIM) is an individual-based, Monte Carlo statistical model designed to predict the exposure of receivers to any stimulus propagating through space and time, which in this analysis is acoustic energy (Frankel *et al.*, 2002). The central component of AIM is the animat movement engine, where parameters control the speed and direction of movement of “animats” (simulated sources or animals) in three-dimensional space at specified time intervals to create a full four-dimensional simulation of the proposed survey.

A separate simulation was created and run for each combination of modeling location and marine mammal species . The simulation area for each modeling location was delineated by four boundaries composed of latitude and longitude lines. These boundaries extended at least one degree of latitude or longitude beyond the extent of the proposed vessel track to ensure 1) the region in which substantial behavioral reactions might be anticipated was captured and 2) an adequate number of animats would be modeled in all directions relative to the airgun array.

Each simulation had approximately 3,000 animats. In most cases, this represented a higher density of animats in the simulation (0.05 animats/km^2) than occurs in the real environment. The modeled animat density value was determined through a sensitivity analysis that examined the stability of the predicted estimate of exposure levels as a function of animat density; the modeled density was determined to accurately capture the full distributional range of probabilities of exposure for the proposed survey. In a later step, potential impacts were normalized back to actual predicted density estimates for each species (**Table 10**).

The potential impacts were also corrected to account for two additional parameters. There was a difference between the amount of modeled survey trackline within each density zone and the actual proposed amount of survey trackline. The potential impacts were scaled by the ratio of the total length of proposed trackline to the modeled length of trackline in each density zone. Secondly, Spectrum Geo, Inc. cannot predict the season in which the proposed survey will occur in each density zone. It was assumed that the entire survey effort would occur within one year and the potential impacts were evenly divided among the four seasons. More precise allocation was not possible, since the spatiotemporal distribution of survey effort is not known, and real-world considerations such as weather and vessel availability will impact the final timing of the survey work.

During the AIM modeling, animals were programmed to remain within the simulation area boundaries through an “aversion” (Section 5.2.2). This behavior prevented the animats from diffusing out of the simulation region, tantamount to the animals present at the start of the modeling scenario staying within the geographical bounds throughout the entire seismic survey, thus a conservative approach.

An AIM simulation consists of a user-specified number of steps forward in time during a 25-hour duration of seismic survey work along proposed track for each modeling site. This duration was selected because of NMFS’ use of the 24-hour reset function for animal exposure estimation procedures. The first hour of model output is discarded, as animals distributions will be unduly influenced by initial conditions (Cordue, 2006).

At each time step, the received sound level and 3D position of each animat were recorded to calculate exposure estimates. Thus unweighted SPL(RMS) and SEL values, as well as M-weighted SEL values, were calculated and compared with their respective criteria. The SEL values at each time step were converted back to intensity and summed, to produce the 24-hr cumulative SEL (SEL_{cum}) value for each individual animat. The numbers of animats with

SPL(RMS) and SEL_{cum} values that exceeded their respective regulatory criteria were considered exposed for that criteria.

8 Mitigation Considerations

8.1 Exclusion Zone

The proposed survey effort will include visual monitoring and mitigation efforts during daylight hours. Protected Species Observers (PSOs) will monitor the 500 m proposed exclusion zone for the pre-ramp up clearance and shut down if animals are detected within the zone.

8.2 Effect of Mitigation on Exposure Estimates

The proposed survey effort will include visual monitoring and mitigation efforts during the daylight hours. Protected Species Observers (PSOs) will monitor the proposed 500 m exclusion zone. The Record of Decision (ROD) for the Final Programmatic Environmental Impact Statement for the Atlantic Outer Continental Shelf Proposed Geological and Geophysical Activities: Mid-Atlantic and South Atlantic Planning Areas (http://www.boem.gov/Record-of-Decision-Atlantic-G-G/) specifies that if a marine mammal is detected within the exclusion zone, then the operation of the airgun array will be suspended for 60 minutes after the last observation of the animal within the exclusion zone. This is done to reduce the acoustic exposure of marine animals and will reduce the number of animals that receive sound levels that exceed regulatory thresholds. Therefore, the effect of visual monitoring and mitigation was included in this analysis using the procedure developed for the National Science Foundation (NSF)-U.S. Geological Survey (USGS) seismic EIS (NSF-USGS, 2011; Appendix B; (NSF-USGS, 2011; Appendix B;(http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/app-b-amr.pdf).

An animal was considered to be “available” for detection by visual monitoring if two conditions were met. Considering the outputs of AIM, which included the received sound level (SEL or SPL), the distance between the source and the animat, and the depth of the animat at each time step, an animal was considered “available” if 1) the distance between the source and animat was less than the exclusion zone range (500 m), and 2) the depth of the animat showed that the animat was at or near the surface. If both of these conditions were true, then the animat was considered “available” to be observed by visual monitoring.

If an animat was determined to be available for detection, a procedure was run to simulate whether the animal would be detected by a virtual PSO. In this procedure, a random number was generated and compared with the probability of detection (*P*(detect)) for the species being modeled (**Table 14**). The detection of probability values were taken from the NSF-USGS seismic EIS (NSF-USGS, 2011; Table B-6; http://www.nsf.gov/geo/oce/envcomp/usgs-nsf-marine-seismic-research/nsf-usgs-final-eis-oeis_3june2011.pdf). If the random number was less than the *P*(detect) value, then the animal was considered detected. Conversely, if the random number was greater than the *P*(detect) value, the animal was modeled as undetected. For example, if there was a 75% probability of detection of a given species (*P*(detect) = 0.75), and the random number generator returned 0.5, then the animal would be considered to be detected. If an animat was detected, then the program would simulate the effect of the airgun source being shut down by setting the received sound levels of ALL animats in the run to 0 for the next 60 minutes, as specified in the ROD.

Two sets of exposure estimates are provided, one with mitigation implemented (**Table 15**) and one set without mitigation (**Table16**).

Table 14. Probability of detection values for different species

Species	Group Size		
	1-16	**17-60**	**>60**
Odontocetes			
Harbor porpoise	0.055	0.090	0.090
Dall's porpoise	0.055	0.090	0.090
Pacific white-sided dolphin	0.309	0.524	0.926
Risso's dolphin	0.309	0.524	0.926
Striped dolphin	0.309	0.524	0.926
Common dolphin	0.309	0.524	0.926
Short-finned pilot whale	0.309	0.524	0.926
Spinner dolphin	0.309	0.524	0.926
Spotted dolphin	0.309	0.524	0.926
Rough-toothed dolphin	0.309	0.524	0.926
Killer whale	0.309	0.524	0.926
False killer whale	0.309	0.524	0.926
Cuvier's beaked whale	0.244	NA	NA
Baird's beaked whale	0.244	NA	NA
Blainville's beaked whale	0.244	NA	NA
Pygmy sperm whale	0.055	0.090	0.090
Dwarf sperm whale	0.055	0.090	0.090
Sperm whale	0.259	NA	NA
Mysticetes			
N right whale	0.259	0.259	NA
Humpback whale	0.259	0.259	NA
Gray whale	0.259	0.259	NA
Blue whale	0.259	0.259	NA
Fin whale	0.259	0.259	NA
Sei whale	0.259	0.259	NA
Bryde's whale	0.259	0.259	NA
Minke whale	0.244	0.244	NA
Pinnipeds			
Harbor seal	0.309	0.524	0.926
N fur seal	0.309	0.524	0.926
Steller's sea lion	0.309	0.524	0.926

Notes: Values used for mitigation simulation in this study are highlighted in tan. This determination was based on typical group size data from Frankel and Vigness-Raposa (2006). NA = group sizes that are not expected to occur.

8.3 Summary and Interpretation of Exposure Estimates

The output results from AIM provide estimated exposures for the historical criteria (160 and 180 dB RMS) and for the Southall et al. (2007) SEL criteria, calculated with (**Table 15**) and without mitigation (**Table 16**). The potential for MMPA incidental harassment Level A (injury) exposures was determined with the dual Southall et al. (2007) M-weighted SEL and unweighted peak SPL criteria and mitigation. All values for unweighted peak SPL criteria were zero. Exposure estimates are also presented for all three assessment criteria for each density zone (Attachment 1). All exposure estimates used scientific rounding to obtain a whole integer. The values calculated with mitigation use the 500 meter exclusion zone. The mitigated values also take into account the time-area closures associated with the critical habitat of the North Atlantic Right Whale (NARW).

It should be noted that if the draft guidance on underwater acoustic thresholds for the onset of PTS (NOAA, 2015) were applied to the proposed survey, there would be a significant reduction in the exposure estimates. The distances to the 180- and 160-dB isopleths were calculated using the historical criteria methodology that does not include any frequency weighting to account for the best available data reflecting animal hearing sensitivities (**Table 17**). For comparison, the distances to the 180- and 160-dB isopleths were calculated with the draft guidance for onset of PTS (NOAA, 2015) using each of the low-, mid-, and high-frequency cetacean weighting functions (**Tables 18-20**). The reduction in the distances to the isopleths can be used to estimate the potential reduction in exposure estimates when comparing the traditional 180- and 160-dB criteria to the draft guidance (NOAA, 2015).

Table 15. Predicted exposures for the regional survey with 500-m exclusion zone and right whale time-area closures (scientific rounding) for historical criteria (160 and 180 dB RMS) and Southall et al. (2007) SEL criteria.

Mysticetes	**160 dB RMS**	**180 dB RMS**	**SEL**
Minke whale	11	1	0
Sei whale	11	1	0
Bryde's whale	11	1	0
Blue whale	12	1	0
Fin whale	26	4	0
North Atlantic right whale	28	5	1
Humpback whale	53	7	1
Odontocetes			
Common dolphin	11,481	1,308	4
Pygmy killer whale	8	1	0
Short-finned pilot whale	8,093	946	0
Long-finned pilot whale	1,497	156	0
Risso's dolphin	5,162	733	1
Northern bottlenose whale	7	1	0
Pygmy sperm whale	22	3	0
Dwarf sperm whale	58	7	0
Atlantic white-sided dolphin	75	7	0
Fraser's dolphin	9	1	0
Sowerby's beaked whale	7	1	0
Blainville's beaked whale	200	29	0
Gervais' beaked whale	200	29	0
True's beaked whale	200	29	0
Killer whale	10	1	0
Melon-headed whale	8	1	0
Harbor porpoise	31	4	0
Sperm whale	1,002	166	0
False killer whale	8	1	0
Pantropical spotted dolphin	2,235	219	0
Clymene dolphin	1,063	104	0
Striped dolphin	14,248	1,014	1
Atlantic spotted dolphin	18,311	1,849	7
Spinner dolphin	10	1	0
Rough-toothed dolphin	44	5	0
Bottlenose dolphin	16,934	1,833	1
Cuvier's beaked whale	1,390	202	0
Sirenians			
West Indian manatee	0	0	0
Pinnipeds			
Hooded seal	0	0	0
Harbor seal	0	0	0
Gray seal	0	0	0

Table 16. Predicted exposures for the regional survey without mitigation (scientific rounding) for historical criteria (160 and 180 dB RMS) and Southall et al. (2007) SEL criteria.

Mysticetes	**160 dB RMS**	**180 dB RMS**	**SEL**
Minke whale	20	4	0
Sei whale	20	4	0
Bryde's whale	20	4	0
Blue whale	20	4	0
Fin whale	42	8	0
North Atlantic right whale	66	14	1
Humpback whale	96	12	0
Odontocetes			
Common dolphin	19,316	2,636	15
Pygmy killer whale	16	4	0
Short-finned pilot whale	11,656	1,398	0
Long-finned pilot whale	2,242	244	0
Risso's dolphin	7,810	1,142	5
Northern bottlenose whale	14	4	0
Pygmy sperm whale	36	6	1
Dwarf sperm whale	96	14	2
Atlantic white-sided dolphin	144	16	0
Fraser's dolphin	16	4	0
Sowerby's beaked whale	14	4	0
Blainville's beaked whale	298	46	0
Gervais' beaked whale	298	46	0
True's beaked whale	298	46	0
Killer whale	20	4	0
Melon-headed whale	16	4	0
Harbor porpoise	60	10	0
Sperm whale	1,498	266	0
False killer whale	16	4	0
Pantropical spotted dolphin	3,838	416	2
Clymene dolphin	1,826	200	1
Striped dolphin	23,188	1,856	3
Atlantic spotted dolphin	31,412	3,652	26
Spinner dolphin	20	4	0
Rough-toothed dolphin	78	12	0
Bottlenose dolphin	25,538	3,108	5
Cuvier's beaked whale	2,060	304	0
Sirenians			
West Indian manatee	0	0	0
Pinnipeds			
Hooded seal	20	4	0
Harbor seal	20	4	0
Gray seal	20	4	0

Table 17. RAM modeled ranges (meters) to 180 dB RMS and 160 dB RMS isopleths calculated using historical criteria methodology

Modeling Site	Maximum distance to 180 dB RMS isopleth	95th percentile distance to 180 dB RMS isopleth	Maximum distance to 160 dB RMS isopleth	95th percentile distance to 160 dB RMS isopleth
1	4,150	3,850	12,950	12,200
2	1,850	1,600	11,450	9,900
3	2,050	1,650	12,700	9,600
4	2,800	2,500	8,450	7,850
5	1,850	1,700	12,200	9,350
6	1,800	1,450	10,950	7,600
7	1,250	1,100	12,700	6,700
8	2,950	2,800	8,100	7,650
9	1,950	1,500	13,050	9,150
10	1,250	1,150	10,150	6,700
11	1,850	1,400	9,800	7,000
12	4,400	3,950	26,550	24,300
13	1,200	1,150	14,650	14,750
14	1,650	1,250	11,550	7,650
17	1,700	1,300	11,550	8,600
18	1,150	1,100	9,750	7,200

Table 18. RAM modeled ranges (meters) to 180 dB RMS and 160 dB RMS isopleths using the draft guidance for onset PTS (NOAA, 2015) with low-frequency cetacean weighting

Modeling Site	Maximum distance to 180 dB RMS isopleth	95th percentile distance to 180 dB RMS isopleth	Maximum distance to 160 dB RMS isopleth	95th percentile distance to 160 dB RMS isopleth	Estimated Reduction in 180 dB LF exposures (%)	Estimated Reduction in 160 dB LF exposures (%)
1	750	600	4,800	4,500	97.6	86.4
2	150	150	1,950	1,750	99.1	96.9
3	150	150	2,050	1,900	99.2	96.1
4	200	150	2,450	2,150	99.6	92.5
5	150	150	2,100	1,850	99.2	96.1
6	150	100	1,900	1,600	99.5	95.6
7	150	100	1,300	1,150	99.2	97.1
8	500	450	3,250	3,050	97.4	84.1
9	150	150	2,050	1,600	99.0	96.9
10	150	50	1,150	1,200	99.8	96.8
11	150	50	1,200	1,150	99.9	97.3
12	650	600	7,200	6,850	97.7	92.1
13	100	100	1,400	1,300	99.2	99.2
14	150	100	1,900	1,400	99.4	96.7
17	150	100	1,900	1,450	99.4	97.2
18	150	50	1,200	1,150	99.8	97.4

Table 19. RAM modeled ranges (meters) to 180 dB RMS and 160 dB RMS isopleths using the draft guidance for onset PTS (NOAA, 2015) with mid-frequency cetacean weighting

Modeling Site	Maximum distance to 180 dB RMS isopleth	95th percentile distance to 180 dB RMS isopleth	Maximum distance to 160 dB RMS isopleth	95th percentile distance to 160 dB RMS isopleth	Estimated Reduction in 180 dB LF exposures (%)	Estimated Reduction in 160 dB LF exposures (%)
1	50	50	100	100	100.0	100.0
2	50	50	100	100	99.9	100.0
3	50	50	100	100	99.9	100.0
4	50	50	100	100	100.0	100.0
5	50	50	100	100	99.9	100.0
6	50	50	100	100	99.9	100.0
7	50	50	100	100	99.8	100.0
8	50	50	100	100	100.0	100.0
9	50	50	100	100	99.9	100.0
10	50	50	100	100	99.8	100.0
11	50	50	100	100	99.9	100.0
12	50	50	100	100	100.0	100.0
13	50	50	100	100	99.8	100.0
14	50	50	100	100	99.8	100.0
17	50	50	100	100	99.9	100.0
18	50	50	100	100	99.8	100.0

Table 20. RAM modeled ranges (meters) to 180 dB RMS and 160 dB RMS isopleths using the draft guidance for onset PTS (NOAA, 2015) with high-frequency cetacean weighting

Modeling Site	Maximum distance to 180 dB RMS isopleth	95th percentile distance to 180 dB RMS isopleth	Maximum distance to 160 dB RMS isopleth	95th percentile distance to 160 dB RMS isopleth	Estimated Reduction in 180 dB LF exposures (%)	Estimated Reduction in 160 dB LF exposures (%)
1	50	50	50	50	100.0	100.0
2	50	50	50	50	99.9	100.0
3	50	50	50	50	99.9	100.0
4	50	50	50	50	100.0	100.0
5	50	50	50	50	99.9	100.0
6	50	50	50	50	99.9	100.0
7	50	50	50	50	99.8	100.0
8	50	50	50	50	100.0	100.0
9	50	50	50	50	99.9	100.0
10	50	50	50	50	99.8	100.0
11	50	50	50	50	99.9	100.0
12	50	50	50	50	100.0	100.0
13	50	50	50	50	99.8	100.0
14	50	50	50	50	99.8	100.0
17	50	50	50	50	99.9	100.0
18	50	50	50	50	99.8	100.0

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Attachment I: Exposure Estimates by Density Zone

MMPA Level B Behavioral Exposures (160 dB RMS threshold) for the Survey

Season	Winter				
Percentage of Effort	0.50				
Density Zone	1	2	3	4	5
Mysticetes					
Minke whale	0.09	2.23	2.01	0.09	0.89
Sei whale	0.09	2.18	2.01	0.09	0.86
Bryde's whale	0.09	2.18	2.01	0.09	0.86
Blue whale	0.09	2.29	2.01	0.09	0.91
Fin whale	0.09	2.29	10.07	0.09	0.91
North Atlantic right whale	0.00	0.00	0.00	3.42	16.75
Humpback whale	0.74	11.62	6.43	0.54	5.04
Odontocetes					
Common dolphin	44.14	1,148.62	2,346.00	34.91	1,520.88
Pygmy killer whale	0.08	2.07	1.50	0.00	0.15
Short-finned pilot whale	30.35	1,669.28	2,268.29	0.00	10.64
Long-finned pilot whale	7.96	418.33	287.87	0.00	2.53
Risso's dolphin	23.58	853.93	1,305.90	0.00	283.17
Northern bottlenose whale	0.09	2.11	1.36	0.00	0.10
Pygmy sperm whale	0.25	5.90	4.09	0.00	0.44
Dwarf sperm whale	0.67	15.72	10.91	0.00	1.18
Atlantic white-sided dolphin	1.42	29.94	12.33	0.00	10.70
Fraser's dolphin	0.08	2.04	1.54	0.09	0.61
Sowerby's beaked whale	0.09	2.11	1.36	0.00	0.10
Blainville's beaked whale	1.04	67.68	43.39	0.00	0.00
Gervais' beaked whale	1.04	67.68	43.39	0.00	0.00
True's beaked whale	1.04	67.68	43.39	0.00	0.00
Killer whale	0.09	2.03	1.66	0.06	0.93
Melon-headed whale	0.08	2.07	1.50	0.00	0.15
Harbor porpoise	0.83	3.72	7.29	0.00	6.73
Sperm whale	4.45	291.65	281.22	0.00	0.08
False killer whale	0.08	2.07	1.50	0.00	0.15
Pantropical spotted dolphin	20.10	476.97	343.65	20.56	183.51
Clymene dolphin	9.56	226.72	163.35	9.77	87.23
Striped dolphin	101.72	4,945.04	3,562.83	24.80	273.20
Atlantic spotted dolphin	79.59	4,427.44	2,881.70	268.98	2,606.96
Spinner dolphin	0.09	2.14	1.54	0.09	0.82
Rough-toothed dolphin	0.42	9.62	6.85	0.00	3.92
Bottlenose dolphin	24.24	955.43	4,537.68	0.00	587.97
Cuvier's beaked whale	7.22	467.41	301.03	0.00	0.10
Pinnipeds					
Hooded seal	0.09	2.23	2.01	0.09	0.89
Harbor seal	0.09	2.23	2.01	0.09	0.89
Gray seal	0.09	2.23	2.01	0.09	0.89

MMPA Level B Behavioral Exposures for the Survey (continued)

Season	Spring				
Percentage of Effort	0.50				
Density Zone	6	7	8	9	10
Mysticetes					
Minke whale	0.08	2.23	2.07	1.62	0.09
Sei whale	0.08	2.41	2.07	1.57	0.09
Bryde's whale	0.08	2.41	2.07	1.57	0.09
Blue whale	0.08	2.28	2.07	1.65	0.09
Fin whale	0.08	2.28	2.07	8.24	0.09
North Atlantic right whale	0.00	0.00	0.00	7.51	0.47
Humpback whale	0.75	11.28	7.25	9.23	0.56
Odontocetes					
Common dolphin	36.83	1,157.87	2,289.68	2,841.52	60.74
Pygmy killer whale	0.08	2.15	1.46	0.26	0.05
Short-finned pilot whale	2.15	1,142.77	2,310.53	657.72	1.64
Long-finned pilot whale	0.69	355.63	330.30	93.64	0.52
Risso's dolphin	1.12	896.32	1,502.45	294.80	0.32
Northern bottlenose whale	0.09	1.93	1.41	0.14	0.03
Pygmy sperm whale	0.27	5.65	4.03	0.79	0.15
Dwarf sperm whale	0.72	15.06	10.75	2.11	0.40
Atlantic white-sided dolphin	0.42	10.71	4.40	4.57	0.63
Fraser's dolphin	0.08	1.92	1.46	1.11	0.13
Sowerby's beaked whale	0.09	1.93	1.41	0.14	0.03
Blainville's beaked whale	0.00	48.30	39.52	0.00	0.00
Gervais' beaked whale	0.00	48.30	39.52	0.00	0.00
True's beaked whale	0.00	48.30	39.52	0.00	0.00
Killer whale	0.08	2.16	1.69	1.59	0.12
Melon-headed whale	0.08	2.15	1.46	0.26	0.05
Harbor porpoise	0.42	2.17	4.51	4.52	0.58
Sperm whale	0.16	286.03	138.46	0.12	0.04
False killer whale	0.08	2.15	1.46	0.26	0.05
Pantropical spotted dolphin	18.72	477.56	326.58	339.54	28.28
Clymene dolphin	8.90	227.00	155.23	161.39	13.44
Striped dolphin	22.59	4,480.08	393.94	409.58	34.12
Atlantic spotted dolphin	1.76	3,362.20	1,288.73	3,074.10	319.37
Spinner dolphin	0.08	2.14	1.46	1.52	0.13
Rough-toothed dolphin	0.36	9.71	6.53	6.90	0.17
Bottlenose dolphin	17.00	6,310.57	4,028.44	438.51	34.01
Cuvier's beaked whale	0.09	334.25	279.46	0.14	0.03
Pinnipeds					
Hooded seal	0.08	2.23	2.07	1.62	0.09
Harbor seal	0.08	2.23	2.07	1.62	0.09
Gray seal	0.08	2.23	2.07	1.62	0.09

MMPA Level A Exposures (180 dB RMS Threshold) for the Survey

Season	Winter				
Percentage of Effort	0.50				
Density Zone	1	2	3	4	5
Mysticetes					
Minke whale	0.01	0.12	0.29	0.03	0.12
Sei whale	0.01	0.09	0.29	0.03	0.13
Bryde's whale	0.01	0.09	0.29	0.03	0.13
Blue whale	0.01	0.19	0.29	0.03	0.13
Fin whale	0.01	0.19	1.47	0.03	0.13
North Atlantic right whale	0.00	0.00	0.00	1.11	2.34
Humpback whale	0.04	0.75	0.88	0.18	0.75
Odontocetes					
Common dolphin	1.71	48.80	261.96	10.80	222.27
Pygmy killer whale	0.00	0.10	0.21	0.00	0.02
Short-finned pilot whale	2.53	82.74	284.05	0.00	1.73
Long-finned pilot whale	0.68	20.73	36.05	0.00	0.41
Risso's dolphin	1.93	85.95	202.91	0.00	44.98
Northern bottlenose whale	0.02	0.27	0.23	0.00	0.01
Pygmy sperm whale	0.04	0.42	0.62	0.00	0.06
Dwarf sperm whale	0.09	1.11	1.66	0.00	0.17
Atlantic white-sided dolphin	0.08	1.56	1.47	0.00	1.64
Fraser's dolphin	0.01	0.13	0.18	0.03	0.12
Sowerby's beaked whale	0.02	0.27	0.23	0.00	0.01
Blainville's beaked whale	0.17	8.77	7.30	0.00	0.00
Gervais' beaked whale	0.17	8.77	7.30	0.00	0.00
True's beaked whale	0.17	8.77	7.30	0.00	0.00
Killer whale	0.01	0.11	0.23	0.02	0.13
Melon-headed whale	0.00	0.10	0.21	0.00	0.02
Harbor porpoise	0.05	0.17	0.95	0.00	0.83
Sperm whale	0.61	37.70	43.61	0.00	0.00
False killer whale	0.00	0.10	0.21	0.00	0.02
Pantropical spotted dolphin	1.16	24.79	41.06	5.97	28.13
Clymene dolphin	0.55	11.78	19.52	2.84	13.37
Striped dolphin	5.20	257.01	425.67	7.21	41.87
Atlantic spotted dolphin	3.92	230.11	344.29	78.17	399.56
Spinner dolphin	0.01	0.11	0.18	0.03	0.13
Rough-toothed dolphin	0.05	1.01	1.02	0.00	0.59
Bottlenose dolphin	0.98	47.94	629.37	0.00	88.08
Cuvier's beaked whale	1.18	60.55	50.62	0.00	0.01
Sirenians					
Pinnipeds					
Hooded seal	0.01	0.12	0.29	0.03	0.12
Harbor seal	0.01	0.12	0.29	0.03	0.12
Gray seal	0.01	0.12	0.29	0.03	0.12

MMPA Level A Exposures (180 dB RMS Threshold) for the Survey (continued)

Season	Spring				
Percentage of Effort	0.50				
Density Zone	6	7	8	9	10
Mysticetes					
Minke whale	0.01	0.15	0.26	0.31	0.02
Sei whale	0.01	0.15	0.26	0.34	0.02
Bryde's whale	0.01	0.15	0.26	0.34	0.02
Blue whale	0.01	0.15	0.26	0.30	0.02
Fin whale	0.01	0.15	0.26	1.50	0.02
North Atlantic right whale	0.00	0.00	0.00	1.33	0.08
Humpback whale	0.05	0.71	1.16	1.91	0.09
Odontocetes					
Common dolphin	1.99	58.89	260.21	430.70	11.06
Pygmy killer whale	0.01	0.09	0.22	0.04	0.01
Short-finned pilot whale	0.21	96.16	369.22	109.24	0.38
Long-finned pilot whale	0.07	29.93	52.78	15.55	0.12
Risso's dolphin	0.14	84.55	252.23	59.92	0.06
Northern bottlenose whale	0.01	0.25	0.23	0.01	0.00
Pygmy sperm whale	0.04	0.47	0.75	0.12	0.04
Dwarf sperm whale	0.11	1.26	2.01	0.33	0.11
Atlantic white-sided dolphin	0.02	0.37	0.63	0.67	0.08
Fraser's dolphin	0.00	0.11	0.21	0.22	0.02
Sowerby's beaked whale	0.01	0.25	0.23	0.01	0.00
Blainville's beaked whale	0.00	6.27	6.52	0.00	0.00
Gervais' beaked whale	0.00	6.27	6.52	0.00	0.00
True's beaked whale	0.00	6.27	6.52	0.00	0.00
Killer whale	0.01	0.13	0.20	0.27	0.02
Melon-headed whale	0.01	0.09	0.22	0.04	0.01
Harbor porpoise	0.02	0.12	0.74	0.64	0.08
Sperm whale	0.02	61.91	22.42	0.01	0.00
False killer whale	0.01	0.09	0.22	0.04	0.01
Pantropical spotted dolphin	0.81	16.49	46.86	49.73	3.71
Clymene dolphin	0.39	7.84	22.27	23.64	1.76
Striped dolphin	0.98	154.72	56.52	59.98	4.48
Atlantic spotted dolphin	0.08	116.12	184.90	450.20	41.90
Spinner dolphin	0.00	0.07	0.21	0.22	0.02
Rough-toothed dolphin	0.03	0.87	0.91	0.98	0.01
Bottlenose dolphin	0.93	370.95	611.41	77.11	5.72
Cuvier's beaked whale	0.01	43.39	46.12	0.01	0.00
Pinnipeds					
Hooded seal	0.01	0.15	0.26	0.31	0.02
Harbor seal	0.01	0.15	0.26	0.31	0.02
Gray seal	0.01	0.15	0.26	0.31	0.02

SEL Level A Exposures (Southall et al. 2007 Criteria) for the Survey

Season	Winter				
Percentage of Effort	0.50				
Density Zone	1	2	3	4	5
Mysticetes					
Minke whale	0.00	0.03	0.00	0.00	0.05
Sei whale	0.00	0.03	0.00	0.00	0.05
Bryde's whale	0.00	0.03	0.00	0.00	0.05
Blue whale	0.00	0.03	0.00	0.00	0.05
Fin whale	0.00	0.03	0.00	0.00	0.05
North Atlantic right whale	0.00	0.00	0.00	0.00	1.09
Humpback whale	0.01	0.19	0.00	0.00	0.31
Odontocetes					
Common dolphin	0.00	0.00	0.00	0.00	4.01
Pygmy killer whale	0.00	0.00	0.00	0.00	0.00
Short-finned pilot whale	0.00	0.00	0.00	0.00	0.05
Long-finned pilot whale	0.00	0.00	0.00	0.00	0.01
Risso's dolphin	0.00	0.00	0.00	0.00	1.47
Northern bottlenose whale	0.00	0.00	0.00	0.00	0.00
Pygmy sperm whale	0.00	0.00	0.00	0.00	0.01
Dwarf sperm whale	0.00	0.00	0.00	0.00	0.02
Atlantic white-sided dolphin	0.00	0.00	0.00	0.00	0.03
Fraser's dolphin	0.00	0.00	0.00	0.00	0.00
Sowerby's beaked whale	0.00	0.00	0.00	0.00	0.00
Blainville's beaked whale	0.00	0.00	0.00	0.00	0.00
Gervais' beaked whale	0.00	0.00	0.00	0.00	0.00
True's beaked whale	0.00	0.00	0.00	0.00	0.00
Killer whale	0.00	0.00	0.00	0.00	0.00
Melon-headed whale	0.00	0.00	0.00	0.00	0.00
Harbor porpoise	0.00	0.00	0.00	0.00	0.25
Sperm whale	0.00	0.00	0.00	0.00	0.00
False killer whale	0.00	0.00	0.00	0.00	0.00
Pantropical spotted dolphin	0.00	0.00	0.00	0.00	0.49
Clymene dolphin	0.00	0.00	0.00	0.00	0.24
Striped dolphin	0.00	0.00	0.00	0.00	0.74
Atlantic spotted dolphin	0.00	0.00	0.00	0.00	7.02
Spinner dolphin	0.00	0.00	0.00	0.00	0.00
Rough-toothed dolphin	0.00	0.00	0.00	0.00	0.01
Bottlenose dolphin	0.00	0.00	0.00	0.00	1.43
Cuvier's beaked whale	0.00	0.00	0.00	0.00	0.00
Pinnipeds					
Hooded seal	0.00	0.03	0.00	0.00	0.05
Harbor seal	0.00	0.03	0.00	0.00	0.05
Gray seal	0.00	0.03	0.00	0.00	0.05

MMPA Level A Exposures (SEL; Southall et al. 2007) for the Survey (continued)

Season	Spring				
Percentage of Effort	0.50				
Density Zone	6	7	8	9	10
Mysticetes					
Minke whale	0.00	0.06	0.00	0.00	0.00
Sei whale	0.00	0.06	0.00	0.00	0.00
Bryde's whale	0.00	0.06	0.00	0.00	0.00
Blue whale	0.00	0.06	0.00	0.00	0.00
Fin whale	0.00	0.06	0.00	0.00	0.00
North Atlantic right whale	0.00	0.00	0.00	0.00	0.00
Humpback whale	0.02	0.35	0.00	0.00	0.00
Odontocetes					
Common dolphin	0.00	0.00	0.00	0.00	0.00
Pygmy killer whale	0.00	0.00	0.00	0.00	0.00
Short-finned pilot whale	0.00	0.00	0.00	0.00	0.00
Long-finned pilot whale	0.00	0.00	0.00	0.00	0.00
Risso's dolphin	0.00	0.00	0.00	0.00	0.00
Northern bottlenose whale	0.00	0.00	0.00	0.00	0.00
Pygmy sperm whale	0.00	0.00	0.00	0.00	0.00
Dwarf sperm whale	0.00	0.00	0.00	0.00	0.00
Atlantic white-sided dolphin	0.00	0.00	0.00	0.00	0.00
Fraser's dolphin	0.00	0.00	0.00	0.00	0.00
Sowerby's beaked whale	0.00	0.00	0.00	0.00	0.00
Blainville's beaked whale	0.00	0.00	0.00	0.00	0.00
Gervais' beaked whale	0.00	0.00	0.00	0.00	0.00
True's beaked whale	0.00	0.00	0.00	0.00	0.00
Killer whale	0.00	0.00	0.00	0.00	0.00
Melon-headed whale	0.00	0.00	0.00	0.00	0.00
Harbor porpoise	0.00	0.00	0.00	0.00	0.00
Sperm whale	0.00	0.00	0.00	0.00	0.00
False killer whale	0.00	0.00	0.00	0.00	0.00
Pantropical spotted dolphin	0.00	0.00	0.00	0.00	0.00
Clymene dolphin	0.00	0.00	0.00	0.00	0.00
Striped dolphin	0.00	0.00	0.00	0.00	0.00
Atlantic spotted dolphin	0.00	0.00	0.00	0.00	0.00
Spinner dolphin	0.00	0.00	0.00	0.00	0.00
Rough-toothed dolphin	0.00	0.00	0.00	0.00	0.00
Bottlenose dolphin	0.00	0.00	0.00	0.00	0.00
Cuvier's beaked whale	0.00	0.00	0.00	0.00	0.00
Pinnipeds					
Hooded seal	0.00	0.06	0.00	0.00	0.00
Harbor seal	0.00	0.06	0.00	0.00	0.00
Gray seal	0.00	0.06	0.00	0.00	0.00