

Request to National Oceanic and Atmospheric Administration (NOAA) for
Incidental Take regulations governing Seismic Surveys on the Outer Continental
Shelf (OCS) of the Gulf of Mexico (GOM) (A response to Subpart I — MMPA
Request Requirements at 50 CFR §216.104)

*Revision to original request package submitted December 20, 2002.
Revisions cover new information that has become available since
submission of the 2002 original and 2004 request packages.*

18 April 2011

**(1) A Detailed Description of the Specific Activity or Class of Activities That Can Be
Expected To Result in Incidental Taking of Marine Mammals;**

Geophysical surveys are performed to obtain information on surface and near-surface geology (high - resolution surveys) and on subsurface structures and formations (seismic surveys and vertical seismic profile (VSP) surveys). Geophysical surveys take place before and after a lease sale. High-resolution surveys done in support of lease operations are authorized under the terms of a lease agreement and are referred to as post-lease surveys. Seismic surveys are performed before and after lease sales, are primarily performed off-lease or on lands leased to a third party, and are authorized under the Bureau of Ocean Energy Management, Regulation, and Enforcement's (BOEMRE) permitting program as mandated under the OCS Lands Act.

BOEMRE defines two primary categories of seismic surveys: (1) deep seismic (OBS, VSP, 2D, 3D, and Wide azimuth surveys (WAZ)), and (2) high resolution surveys. In general, seismic surveys are deep penetrating and are used to obtain data about geologic formations greater than 300 m below the seafloor. Typical seismic surveying operations tow a seismic sound source, 8 to 12 meters below the sea surface. The seismic sound source is generally an air gun array but may also be a boomer, sparker or other technology, and one or more streamers (cable(s) with hydrophone signal receivers) are also towed behind the vessel. An alternative to streamers is the deployment of seafloor geophones either connected to ocean bottom cables (OBC) or nodes placed individually on the seafloor (OBS). The airgun array produces underwater sound waves by releasing compressed air into the water column, creating an acoustical energy pulse. The intermittent release of compressed air creates a regular series of strong acoustic impulses separated by silent periods lasting up to 16 seconds, depending on survey type and depth to the target formations. The acoustic signals are reflected off subsurface structures and sediments and recorded back near the surface via the hydrophones in the streamer(s) or nodes/geophones. Streamers are often 3 to 12 km in length and the speed at which the vessels tow them varies depending on the type of survey, but is typically between 3 to 4.5 kt (about 5 to 8km/h) with gear deployed.

High-resolution surveys collect data on surface and near-surface geology used to identify archeological sites, potential shallow geologic and manmade hazards for engineering, and site planning for bottom-founded structures. Seismic surveys include two-dimensional (2-D), three-dimensional (3-D) surveys, and Wide Azimuth Surveys (WAZ). Data from these surveys are used to map the structural characteristics of stratigraphically important horizons in order to identify potential hydrocarbon traps. These high resolution surveys mainly use a single air gun but other sound sources, such as boomers, sparkers, chirpers, may also be used. These sound sources are powered typically by mechanically or electromagnetically. (Further detail is provided in the sections below and in our Final PEA (Minerals Management Service (MMS), 2004.)

Deep Seismic

For 2-D seismic surveys, a single streamer is towed behind the survey vessel, together with a single source or airgun array. Seismic vessels generally follow a systematic pattern during a survey, typically a simple grid pattern for 2-D work with lines no closer than half a kilometer. In simplistic terms, 3-D

surveys collect a very large number of 2-D slices, with minimum line separations of only 25 to 30 m. A 3-D survey may take many months to complete (e.g. 3-18) and involves a precise definition of the survey area and transects, including multiple passes to cover a given survey area. For seismic surveys, 3-D methods represent a substantial improvement in resolution and useful information relative to 2-D methods. Most areas in the Gulf of Mexico previously surveyed using 2-D have been, or will be, surveyed using 3-D.

The 3-D seismic surveying provides the opportunity to create higher resolution subsurface images and to resolve imaging challenges, thereby enabling a more accurate assessment of potential hydrocarbon reservoirs. As a result the oil and gas industry is able to optimally locate exploration and development wells, thereby maximizing the success rate of exploration wells and minimizing the number of wells required to develop a field. State-of-the-art interactive computer mapping systems can handle much denser data coverage than the older 2-D seismic surveys. Multiple-source and multiple-streamer technologies are used for 3-D seismic surveys. A typical 3-D survey might employ a dual array of 18 guns per array. At 10 m from the source, the pressure experienced is approximately ambient pressure plus 1 atmosphere (atm). The streamer array might consist of 6 to 8 parallel cables, each 3,000 to 12,000 m long, spaced 25 to 100 m apart. An 8-streamer array used for deepwater surveys is typically 700 m wide. A series of 3-D surveys collected over time (commonly referred to as four-dimensional or 4-D seismic surveying) is used for reservoir monitoring and management (the movement of oil, gas, and water in reservoirs can be observed over time). Increasingly, the data collected in a 3-D seismic survey can be processed to provide near surface images adequate for many of the needs previously met by high-resolution surveys.

Wide-azimuth towed-streamer (WAZ) acquisition has emerged in the last few years as a step change in marine acquisition technology in the Gulf of Mexico. This came about because the risky exploration and development of deepwater subsalt reservoirs required seismic data to have better illumination, higher signal-to-noise ratio, and improved resolution. Wide azimuth acquisition configurations involve multiple vessels operating concurrently in a variety of source vessel-to-acquisition vessel geometries. Several source vessels (usually 2-4) are used in coordination with single or dual receiver vessels either in a parallel or rectangular arrangement with a typical 1200-m vessel spacing to maximize the azimuthal quality of data acquired. It is not uncommon to have sources also deployed from the receiver vessels in addition to source-only vessels. This improves the signal-to-noise ratio and helps to better define the salt and sub-salt structures in the deep waters of the GOM. Coiled (spiral) surveys are a further refinement of the wide azimuth acquisition of subsalt data. These surveys can consist of a single source/ receiver arrangement or a multi vessel operation with multi sources where the vessels navigate in a coiled or spiral pattern over the area of acquisition.

Deep seismic surveying is deeper penetration, high energy and low frequency (2-D, 3-D, 4-D or WAZ) and may also be done on leased blocks for more accurate identification of potential reservoirs, thereby aiding in the identification of additional reservoirs in "known" fields. This 3-D technology can be used in developed areas to identify bypassed hydrocarbon-bearing zones in currently producing formations and new productive horizons near or below currently producing formations. It can also be used in developed areas for reservoir monitoring and field management. Four-dimensional (4D) seismic surveying is predominantly used for on-lease reservoir monitoring and management. Through time-lapsed surveys, the movement of oil, gas, and water in reservoirs can be observed over time, and that critical information used to adjust production techniques and decisions, leading to more efficient production of the reservoir and the ultimate recovery of a greater portion of the original oil and gas in place. Surveying may occur periodically throughout the productive life of a lease, as frequently as every six months.

Ocean Bottom Surveys (OBS)

Ocean bottom cable (OBC) surveys were originally designed to enable seismic surveys in congested areas, such as producing fields, with their many platforms and producing facilities. Autonomous nodes, deployed and retrieved by either cable or remotely operated vehicles (ROVs), are now used as an alternative to cables. OBC cable surveys have been found to be useful for obtaining multi-component (i.e., seismic pressure, vertical, and the two horizontal motions of the water bottom, or seafloor) information.

OBC surveys and nodal acquisition require the use of multiple ships (i.e., usually two ships for cable or node layout/pickup, one ship for recording, one ship for shooting, and two utility boats). These ships are generally smaller than those used in streamer operations, and the utility boats can be very small. Operations are conducted “around the clock” and begin by dropping the cables off the back of the layout boat or by deployment of the nodal receivers by ROVs. Cable length or the numbers of nodes depend upon the survey demands; it is typically 4.2 km but can be up to 12 km. However depending on spacing and surveys size, hundreds of nodes can be deployed and re-deployed over the span of the survey. Groups of seismic detectors, usually hydrophones and vertical motion geophones, are attached to the cable in intervals of 25 to 50 m or autonomous nodes are spaced similarly. Multiple cables/ nodes are laid parallel to each other using this layout method with a 50 m-interval between cables/ nodes. Typically dual airgun arrays are used on a single source vessel. When the cable/ node is in place, a ship towing an airgun array (which is the same airgun array used for streamer work) passes between the cables/ nodes, firing every 25 m. Sometimes a faster source ship speed of 6 knots, instead of the normal 4.5 knots speed, is used with a decrease in time between gun firings. After a source line is shot, the source ship takes about 10 to 15 minutes to turn around and pass down between the next two cables or line of nodes. When a cable/node is no longer needed to record seismic data, it is picked up by the cable pickup ship and is moved over to the next position where it is needed. The nodes are retrieved by an ROV. A particular cable/node can lay on the bottom anywhere from 2 hours to several days, depending upon operation conditions. Normally a cable will be left in place about 24 hours. However, nodes may remain in place until the survey is completed or recovered and then re-deployed by an ROV.

Location of the cables/nodes on the bottom is done by acoustic pingers located at the detector groups and by using the time of first arrival of the seismic pulse at the detector group. The acoustic pinger uses frequencies in the 9-13 kHz range. A detector group is a node or group of nodes that enable the seismic ship to accurately determine node location. To obtain more accurate first arrival times, the seismic data are recorded with less electronic filtering than is normally used. This detailed location is combined with normal GPS navigational data collected on the source ship. In deep-water, the process of accurately locating bottom cables/ nodes is more difficult because of the effects of irregular water bottoms and of the thermal layers, which affect travel times and travel paths, thus causing positioning errors.

High Resolution Surveys

High-resolution site surveys are conducted to investigate the shallow subsurface for geohazards and soil conditions, as well as to identify potential benthic biological communities (or habitats) and archaeological resources in support of review and mitigation measures for OCS exploration and development plans. Information also can be recovered at much greater depths, so that some surveys are used for exploration purposes. A typical operation consists of a ship towing an airgun (about 25 m behind the ship) and a 600-m streamer cable with a tail buoy (about 700 m behind the ship). The ship travels at 3 to 3.5 kn (5.6 to 6.5 km/h), and the airgun is fired every 7 to 8 s (or about every 12.5 m). Typical surveys cover one lease block, which is 4.8 km on a side. BOEMRE regulations require information be gathered on a 300- by 900-m grid, which amounts to about 129 line km of data per lease block. If the BOEMRE has identified a block as having a high probability for the presence of historic archaeological resources (i.e., shipwrecks), grid points must be on a 50 m spacing (i.e., pursuant to NTL No. 2005-G07). Including line turns, the time to survey one block is about 36 h; however, streamer and airgun deployment and other operations add to the total survey time.

High-resolution surveying is done on a site-specific or lease-specific basis or along a proposed pipeline route. These surveys are used to identify potential shallow, geologic hazards for engineering and site planning for bottom-founded structures. They are also used to identify environmental resources such as hard-bottom areas, topographic features, or historical archaeological resources. Post-lease, high-resolution seismic surveying is usually done at least once for each lease, except for leases where previous surveys preclude the requirement for new surveys.

High resolution 3-D surveys using ships towing multiple streamer cables have become available, however their use in the GOM is uncommon. Since multiple streamers are towed, the ships tend to be slightly larger (47 m vs. 37 m). Up to six streamers 100 to 200 m long are used with a tri-cluster of airguns.

(2) The Date(s) and Duration of Such Activity and the Specific Geographical Region Where It Will Occur;

Oil and gas exploration on parts of the continental shelf of the northern GOM (U.S. waters north of the Exclusive Economic Zone (EEZ) boundary) is in a mature state, although large discoveries are expected in deeper waters. The Eastern GOM remains largely under explored. New seismic survey activity is expected to occur in the Eastern Planning Area, however industry activity in the Eastern Planning Area has historically been limited to the westernmost portions of the planning area due to lack of availability of acreage for lease and is usually defined by the 5-Year Leasing Program (see <http://www.boemre.gov/5-year/>). Figure 2-1 defines BOEMRE planning areas and administrative boundaries.

The different types of geophysical survey activity in the northern Gulf can occur on any day of a given year during the time period of the requested rule (5 years). Specific geophysical surveys may span one day, weeks, or months. Geophysical surveys may be conducted in any Federal or state waters of the Gulf of Mexico. Figure 2-2 illustrates the 9 acoustic regions discussed below. Tables 2-1 through 2-5 provide the number of surveys, by blocks surveyed (~ 3 miles x 3 miles), for nine regions (Central, Western and Eastern – Shelf, Slope, Deep), by projected estimation of the anticipated level of effort (e.g., for 2010 – 2014), for each of the survey types. For OBS surveys in Table 2-1, “Light” is assumed to be approximately 50 blocks surveyed. For each of the tables, “shelf” is defined as 0-200 m, “slope” is 200 – 1000 m, and “deep” is considered >1000 m.

Figure 2-1. BOEMRE's Gulf of Mexico Planning Areas and Administrative Boundaries

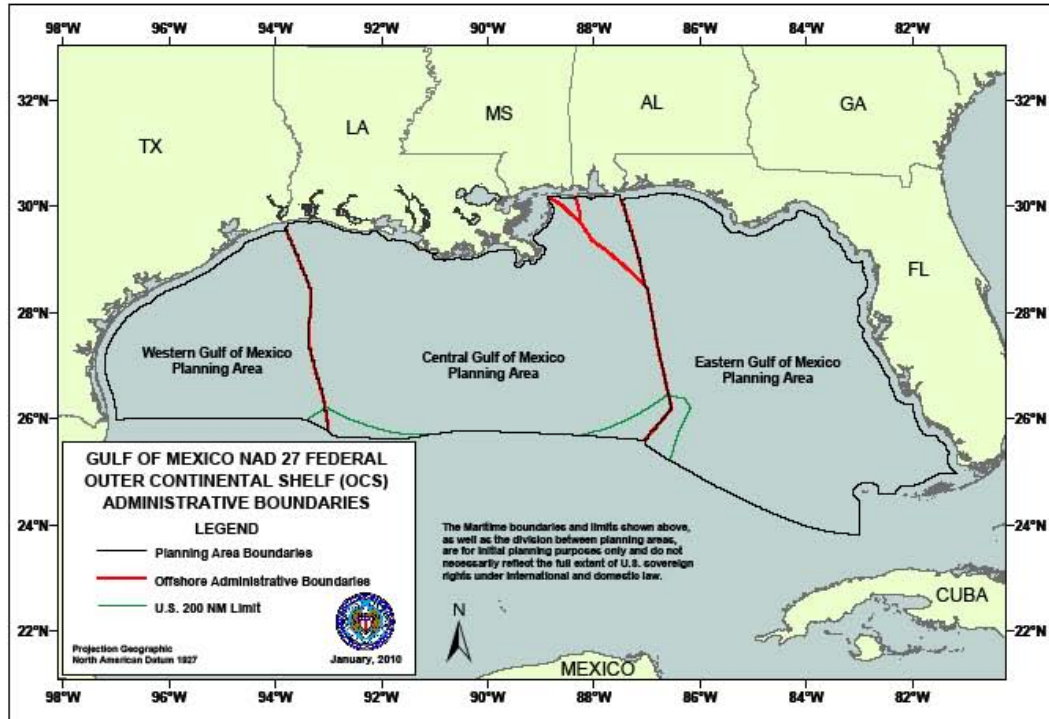


Figure 2-2. Acoustic Regions and Representative Model Sites in the Gulf of Mexico.

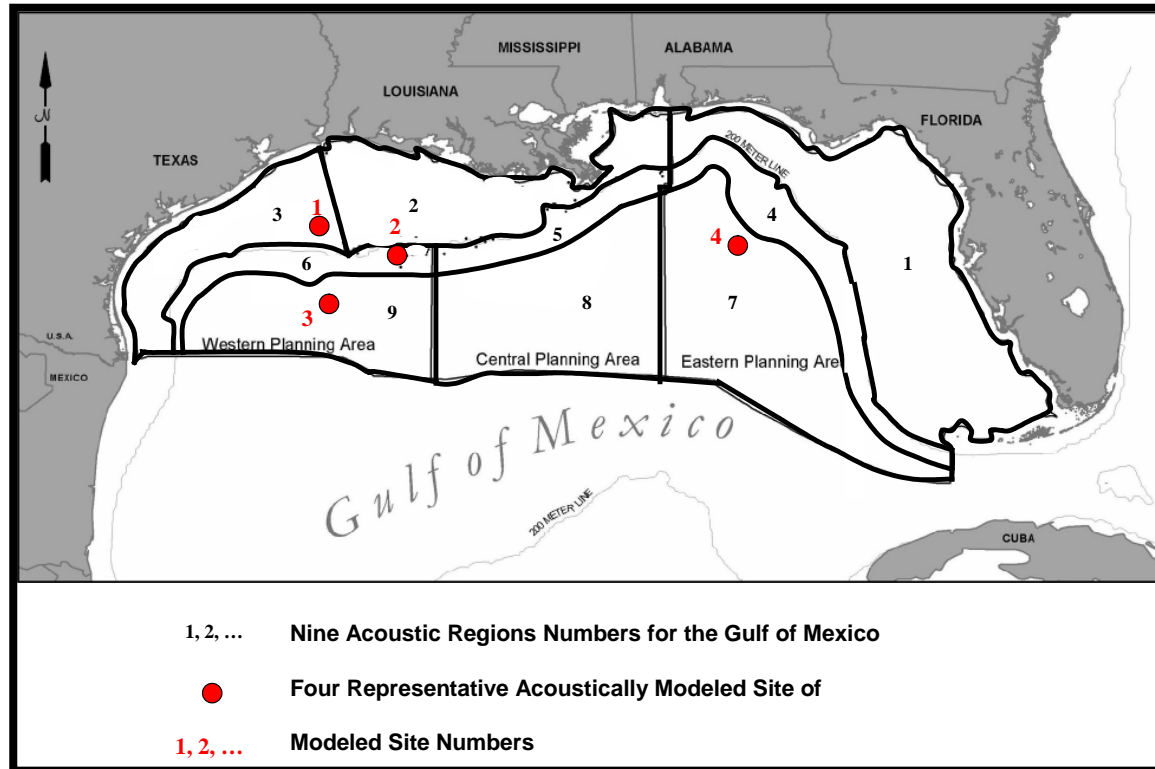


Table 2-1. OBS Surveys in each BOEMRE Region, by Year, Number of Blocks and Approximate Depth Zone
 “E” indicates Eastern Planning Area; “C” indicates Central Planning Area; and “W” indicates Western Planning Area

Depth Zone: BOEMRE Planning Region:	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2012	0	50	50	0	50	0	0	50	0
2013	0	50	50	0	50	0	0	50	0
2014	0	50	50	0	50	0	0	50	0
2015	0	50	50	0	50	0	0	50	0
2016	0	50	50	0	50	0	0	50	0
2017	0	50	50	0	50	0	0	50	0

Table 2-2. Number of Lease Blocks Surveyed by Year, and Approximate Depth Zone, by 2-D Seismic in each BOEMRE Region.

Depth Zone: BOEMRE Planning Region:	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2012	10434.	92.2	246.7	10434.	92.2	246.7	15651.	925.6	246.7
2013	2296.5	640.4	1666.8	3444.7	640.4	1666.8	5741.2	5756.8	3333.6
2014	74.1	134.8	277.8	111.1	134.8	277.8	185.2	1211.9	555.6
2015	1259.4	134.8	277.8	1889.0	134.8	277.8	3148.4	1211.9	555.6
2016	14964.	134.8	277.8	22446.	134.8	277.8	37410.	1211.9	555.6
2017	12186.	134.8	277.8	18279.	134.8	277.8	30465.	1211.9	555.6

Table 2-3. Number of Lease Blocks Surveyed by Year, and Approximate Depth Zone, by 3-D Seismic in each BOEMRE Region.

Depth Zone: BOEMRE Planning Region:	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2012	137.	648.	219.	137.3	108.4	0	205.	1080	657.
2013	241.	357.	48.2	362.1	60.0	0	603.	715.	192.
2014	140.	279.	6.0	210.9	46.1	0	351.	746.	24.0
2015	40.6	525.	43.0	60.9	86.5	0	101.	1400	172.
2016	130.	368.	6.0	195.9	60.7	0	326.	982.	24.0
2017	74.6	347.	46.0	111.9	57.3	0	186.	927.	184.

Table 2-4. Number of Lease Blocks Surveyed by Year, and Approximate Depth Zone, by WAZ Surveys in each BOEMRE Region.

Depth Zone: BOEMRE Planning Region:	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2012	0	367.	81.8	0	734.1	163.4	0	1192	816.
2013	0	272.	66.9	25.0	816.1	133.6	0	1196	534.
2014	0	232.	89.2	12.5	814.2	178.2	12.5	1163	712.
2015	0	268.	79.3	12.5	939.5	158.4	12.5	1342	633.
2016	0	200.	51.6	276.0	702.9	103.1	276.	1004	412.
2017	0	264.	92.8	213.5	924.7	185.5	213.	1321	741.

Table 2-5. Number of Lease Blocks Surveyed by Year, and Approximate Depth Zone, by 2-D High Resolution Surveys in each BOEMRE Region.

Depth Zone: BOEMRE Planning Region:	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2012	0.54	33.26	2.66	0.54	33.26	2.66	0.54	33.26	2.66
2013	0.58	36.32	2.91	0.58	36.32	2.91	0.58	36.32	2.91
2014	0.64	39.38	3.15	0.64	39.38	3.15	0.64	39.38	3.15
2015	0.64	39.38	3.15	0.64	39.38	3.15	0.64	39.38	3.15
2016	0.61	37.85	3.03	0.61	37.85	3.03	0.61	37.85	3.03
2017	0.61	37.85	3.03	0.61	37.85	3.03	0.61	37.85	3.03

(3) The Species and Numbers of Marine Mammals Likely To Be Found within the Activity Area;

See table below.

Table 3.1. Population Estimates for Marine Mammal Species in the Northern Gulf of Mexico

Species	Best Population Estimate ¹ (Minimum estimates)	ESA Status	MMPA Status
Killer Whale (<i>Orcinus orca</i>)	49 (28)	Non-listed	Not classified
False Killer Whale (<i>Pseudorca crassidens</i>)	777 (501)	Non-listed	Not classified
Pygmy Killer Whale (<i>Feresa attenuata</i>)	323 (203)	Non-listed	Not classified
Dwarf Sperm Whale (<i>Kogia sima</i>)	453 ^a (340)	Non-listed	Not classified
Pygmy Sperm Whale (<i>Kogia breviceps</i>)	453 ^a (340)	Non-listed	Not classified
Melon-headed Whale (<i>Peponocephala electra</i>)	2,283 (1,293)	Non-listed	Not classified
Risso's Dolphin (<i>Grampus griseus</i>)	1,589 (1,271)	Non-listed	Not classified
Short-finned Pilot Whale (<i>Globicephala macrorhynchus</i>)	716 (542)	Non-listed	Not classified
Sperm Whale (<i>Physeter macrocephalus</i>)	1,665 (1,409)	Endangered	Depleted
Bryde's Whale (<i>Balaenoptera edeni</i>)	15 (5)	Non-listed	Not classified
Cuvier's Beaked Whale (<i>Ziphius cavirostris</i>)	65 (39)	Non-listed	Not classified
Blainville's Beaked Whale (<i>Mesoplodon densirostris</i>)	57 ^b (24)	Non-listed	Not classified
Gervais' Beaked Whale (<i>Mesoplodon europaeus</i>)	57 ^b (24)	Non-listed	Not classified
Bottlenose Dolphin (<i>Turisops truncatus</i>)	42,841 ^c (UNK)	Non-listed	Not classified
Atlantic Spotted Dolphin (<i>Stenella frontalis</i>)	27,393 ^d (UNK)	Non-listed	Not classified
Pantropical Spotted Dolphin (<i>Stenella attenuatus</i>)	34,067 (29,311)	Non-listed	Not classified
Striped Dolphin (<i>Stenella coeruleoalba</i>)	3,325 (2,266)	Non-listed	Not classified
Spinner Dolphin (<i>Stenella longirostris</i>)	1,989 (1,356)	Non-listed	Not classified
Rough-toothed Dolphin (<i>Steno bredanensis</i>)	2,942 ^d (UNK)	Non-listed	Not classified
Clymene Dolphin (<i>Stenella clymene</i>)	6,575 (4,901)	Non-listed	Not classified

Species	Best Population Estimate ¹ (Minimum estimates)	ESA Status	MMPA Status
Fraser's Dolphin (<i>Lagenodelphis hosei</i>)	726 ^e (UNK)	Non-listed	Not classified
Absent from GOM Stock Assessment:			
Northern Right Whale (<i>Eubalaena glacialis</i>)	Extralimital ^f	Endangered	Depleted
Minke Whale (<i>Balaenoptera acutorostrata</i>)	Rare ^g	Non-listed	Not classified
Sei Whale (<i>Balaenoptera edeni</i>)	Rare	Endangered	Depleted
Blue Whale (<i>Balaenoptera musculus</i>)	Extralimital	Endangered	Depleted
Fin Whale (<i>Balaenoptera physalus</i>)	Rare	Endangered	Depleted
Humpback Whale (<i>Megaptera novaeangliae</i>)	Rare	Endangered	Depleted
Sowerby's Beaked Whale (<i>Mesoplodon bidens</i>)	Extralimital	Non-listed	Not classified

¹ Source: U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments – 2009 (Waring et al. 2009).

^a This estimate may include both the dwarf and pygmy sperm whales.

^b This estimate includes Gervais' beaked whales and Blainville's beaked whales.

^c This estimate is from the Gulf of Mexico Marine Mammal Stock Assessments – 2007 (Waring et al. 2007). This estimate combines abundance estimates from the Northern Gulf of Mexico Oceanic Stock (3,708), Continental Shelf Stock (21,531), and Coastal Stock (17,602). The coastal stock population size has not been estimated for more than 8 years and these data are from 1992-1994..

^d This estimate is from the Gulf of Mexico Marine Mammal Stock Assessments – 2007 (Waring et al. , 2007).

^e This estimate is from the Gulf of Mexico Marine Mammal Stock Assessments – 2005 (Waring et al. , 2005).

^f Extralimital: known on the basis of only a few records that probably resulted from unusual wanderings of animals into the region (Würsig et al. 2000).

^g Rare: present in such small numbers throughout the region that it is seldom seen (Würsig et al. 2000).

(4) 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;

The Gulf of Mexico is a semi-enclosed marginal sea of the Atlantic Ocean bounded by the United States, Mexico, and Cuba. Entry from the Atlantic Ocean into the Gulf of Mexico is gained through the Straits of Florida, and entry from the Caribbean Sea is gained through the Yucatan Channel. The Gulf is characterized by a very wide, gently sloping continental shelf around most of its margin. The only area of the U.S. Gulf (north of the Exclusive Economic Zone) where the water depth reaches 200 m within 50 km of the shore is off the Mississippi River delta. Continental shelf waters (< 200 m deep) comprise about 35 percent of the Gulf surface and continental slope waters (200-3,000 m) make up another 40 percent (Würsig et al. 2000). In contrast to the smooth, gentle slope of the continental shelf, the Gulf continental slope is steep and irregular with canyons and knolls. The remaining 25 percent of the Gulf waters are the abyssal depths, mainly of the Sigsbee Abyssal Plain.

The U.S. Gulf of Mexico marine mammal community is diverse and distributed throughout the northern Gulf waters. The only two species that are commonly found in continental shelf waters are bottlenose dolphins and Atlantic spotted dolphins (Fulling et al. 2003). Slope waters are routinely inhabited by 20 species, most of which have worldwide distribution in deep, warm-temperate to tropical waters. Two exceptions to worldwide distributions are Atlantic spotted dolphins (*Stenella frontalis*) and clymene dolphins (*Stenella clymene*). Common in the Gulf, these two species are found only in the Atlantic and its associated waters.

Listed below are the individual species that routinely inhabit the U.S. Gulf of Mexico and, thus, might be affected by the subject activities. Mullin and Fulling (2004) reported that many of these species were widely distributed but some had a more regional distribution and these are noted in species accounts. It was also reported that there was some evidence of seasonal changes in slope waters species abundance

but that the Gulf marine mammal community remained diverse and abundant throughout the year and no commonly occurring species vacated the slope waters seasonally (Mullin et al. 2004). Seasonal observations are also reported under individual species accounts. Unless otherwise cited, the information in the individual species accounts is from the 2009 Stock Assessment Report available on the NOAA Office of Protected Resources' website. Additional information on marine mammal species, abundance, and distribution can be found in MMS (2004).

There are species that have been reported from Gulf waters, either by sighting or stranding, that are not included in the species accounts (Wursig et al. 2000; Mullin and Fulling 2004). These species include the blue whale (*Balaenoptera musculus*), the northern right whale (*Eubalaena glacialis*), and the Sowerby's beaked whale (*Mesoplodon bidens*), all considered extralimital in the Gulf of Mexico, and the humpback whale (*Megaptera novaeangliae*), the fin whale (*Balaenoptera physalus*), the sei whale (*Balaenoptera borealis*), and the minke whale (*Balaenoptera acutorostrata*), all considered rare occasional migrants in the Gulf. Because of the rarity of these species in the Gulf, no potential effect from subject activities is expected.

For all the species listed below, information about the optimum sustainable population (OSP) and the potential biological removal (PBR) are included. OSP is defined in 16 U.S.C. §1362(9) as "the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." PBR is defined in 16 U.S.C. §1362(20) as "the maximum number of animals, not including natural mortalities, that may be removed from a marine mammal stock while allowing that stock to reach or maintain its optimum sustainable population."

Killer Whale (*Orcinus orca*)

Status

The population of killer whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

This species is not listed as endangered or threatened under the Endangered Species Act. The status of killer whales in the northern Gulf of Mexico, relative to the optimum sustainable population (OSP), is unknown. There are not sufficient data to assess population trends for this species. This stock is not a strategic stock because it is assumed that the average annual human-related serious injury and mortality does not exceed potential biological removal (PBR).

Distribution

The killer whale is a cosmopolitan species that occurs in all oceans and seas and is considered the most widespread cetacean worldwide. These animals are not limited by such habitat features as water depth or temperature (Reeves et al. 2002). Killer whale sightings in the northern GOM have primarily been in deeper waters off the continental shelf (>200 m).

Seasonal Distribution

Killer whale sightings in the northern Gulf of Mexico have occurred primarily in summer months (May through September). Thirty-two individual killer whales have been photo-identified in the GOM with 6 resighted over a 5-year period and 1 resighted over 10 years. Three of the resightings involved individual whales that had moved over 1,100 km from the original sighting location (O'Sullivan and Mullin, 1997). It is not known whether killer whales in the northern GOM remain within the GOM or range more widely (Wursig et al. 2000). However, resighting individual whales in similar seasons in subsequent years would suggest that either the animals return seasonally to the northern Gulf after moving out of the area (particularly if surveys at other times of the year did not find killer whales) or that killer whales remain in the northern Gulf year.

False Killer Whale (*Pseudorca crassidens*)

Status

The population of false killer whales in the Gulf of Mexico is provisionally being considered one stock for management purposes by NMFS. Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

This species is not listed as endangered or threatened under the Endangered Species Act. The status of false killer whales in the northern Gulf of Mexico, relative to the OSP, is unknown. There are not sufficient data to assess population trends for this species. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The false killer whale occurs in oceanic depths (usually >1,000 m) of all tropical and warm temperate waters (Reeves et al. 2002). Species sightings in the northern GOM occurred primarily in the deep waters off the continental shelf.

Seasonal Distribution

False killer whales have only been sighted during the late spring and summer by extensive NMFS aerial and shipboard surveys. Whether this indicates seasonal distribution or is an artifact of survey effort is not clear.

Pygmy Killer Whale (*Feresa attenuata*)

Status

The population of pygmy killer whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

Pygmy killer whales are not listed as threatened or endangered under the Endangered Species Act. The status of pygmy killer whales in the northern Gulf of Mexico, relative to the OSP, is unknown. There are not sufficient data to assess population trends for this species. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The pygmy killer whale is an oceanic species with a worldwide, pantropical range (Reeves et al. 2002). Species sightings in the northern GOM occurred primarily in the deeper oceanic waters off the continental shelf.

Seasonal Distribution

Sightings of pygmy killer whales have occurred in all seasons in the northern GOM during NMFS surveys.

Dwarf Sperm Whale (*Kogia sima*)

Status

The population of dwarf sperm whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to

differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of dwarf sperm whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The dwarf sperm whale is distributed worldwide in temperate to tropical waters. Reeves et al. (2002) reported that pygmy sperm whales are thought to inhabit waters primarily seaward of the continental shelf and that dwarf sperm whales are “somewhat more coastal,” occurring in shelf-edge and slope waters. In the northern Gulf of Mexico, sightings of dwarf and pygmy sperm whales occur primarily along the continental shelf edge and over the deeper waters off the continental shelf. These two species are virtually impossible to differentiate in the field.

Seasonal Distribution

Dwarf sperm whales and their congeners, pygmy sperm whales, are often combined into a *Kogia* category because of the inability to differentiate the two species at sea. Sightings of *Kogia* spp. have been documented in all seasons in the northern Gulf of Mexico.

Pygmy Sperm Whale (*Kogia breviceps*)

Status

The population of pygmy sperm whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of pygmy sperm whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The pygmy sperm whale is distributed worldwide in temperate to tropical waters. Reeves et al. (2002) reported that pygmy sperm whales are thought to inhabit waters primarily seaward of the continental shelf and that dwarf sperm whales are “somewhat more coastal,” occurring in shelf-edge and slope waters. In the northern Gulf of Mexico, sightings of dwarf and pygmy sperm whales occur primarily along the continental shelf edge and over the deeper waters off the continental shelf. These two species are virtually impossible to differentiate in the field.

Seasonal Distribution

Pygmy sperm whales and their congeners, dwarf sperm whales, are often combined into a *Kogia* category because of the inability to differentiate the two species at sea. Sightings of *Kogia* spp. have been documented in all seasons in the northern Gulf of Mexico.

Melon-headed Whale (*Peponocephala electra*)

Status

The population of melon-headed whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of melon-headed whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. This Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

Melon-headed whales are distributed worldwide in tropical to sub-tropical waters (Reeves et al. 2002). In the northern Gulf of Mexico, sightings have occurred primarily in deeper waters off the continental shelf.

Seasonal Distribution

Sightings of melon-headed whales have occurred in all seasons in the northern GOM during NMFS surveys.

Risso's Dolphin (*Grampus griseus*)

Status

The population of Risso's dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of Risso's dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The Risso's dolphin is distributed worldwide in tropical and warm temperate waters (Reeves et al. 2002). Typically found in deep water (>1,000 m) on the upper continental slope, Risso's dolphins are known to move into more shallow water on the continental shelf, perhaps following prey. Sightings of this species in the northern GOM occurred primarily along the continental shelf and continental slope.

Seasonal Distribution

Sightings of Risso's dolphins have occurred in all seasons in the northern GOM during NMFS surveys. Mullin and Fulling (2004) report that in the northeastern GOM Risso's dolphins were three times more abundant in winter than in summer.

Short-finned Pilot Whale (*Globicephala macrorhynchus*)

Status

The population of short-finned pilot whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to

differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of short-finned pilot whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The short-finned pilot whale is widespread and abundant in warm temperate to tropical waters of the world (Reeves et al. 2002). Sightings of this species in the northern GOM occurred primarily along the continental shelf and continental slope.

Seasonal Distribution

Sightings of short-finned pilot whales have occurred in all seasons in the northern GOM during NMFS surveys.

Sperm Whale (*Physeter macrocephalus*)

Status

The population of sperm whales in the Gulf of Mexico constitutes a distinct stock from other Atlantic ocean stocks(s) (Jochens et al. 2008) and is considered as such for management purposes by NMFS. The status of sperm whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is listed under the Endangered Species Act and is the only commonly occurring marine mammal in the Gulf of Mexico with this status. Insufficient data prohibits determination of population trends. Sperm whales are designated as strategic because of their endangered status.

Distribution

Sperm whales are found worldwide in ice-free waters from the equator to the edges of the polar ice pack (Reeves et al. 2002). In the northern Gulf of Mexico, sperm whales are widely distributed throughout oceanic waters (>200 m). The highest densities of sperm whales in the Gulf are in the slope waters between 200 and 2,000 m deep (Mullin and Fulling, 2004). Mullin and Fulling (2004) report increased sightings of sperm whales off the Mississippi River delta, and in the southeastern Gulf, west of the Dry Tortugas. They speculate that these whale concentrations may be due to the primary productivity associated with the Mississippi River plume and the productivity bolstered by nutrient upwelling along the Loop Current front and periodic formations of cyclonic gyres in the southeast Gulf, respectively.

Seasonal Distribution

Sperm whales have been sighted in all seasons in the Gulf of Mexico on NOAA surveys. However, sightings have been more common during the summer months.

Bryde's Whale (*Balaenoptera edeni*)

Status

The population of Bryde's whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation and/or residency.

The status of Bryde's whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data

prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The Bryde's whale is distributed worldwide in tropical and subtropical waters (Reeves, et al. 2002). Species sightings in the northern Gulf of Mexico are not common and have almost exclusively occurred in the eastern Gulf. Mullin and Fulling (2004) reported that all four Bryde's whale sightings made on NOAA surveys between 1996 and 2001 were in northeastern Gulf slope waters (200 – 1,000 m).

Seasonal Distribution

Sightings of Bryde's whales have occurred in the northern Gulf of Mexico mainly during the spring-summer months; however, Jefferson et al. (1992) reported that strandings have occurred throughout the year.

Cuvier's Beaked Whale (*Ziphius cavirostris*)

Status

The population of Cuvier's beaked whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. Although inadequate biological information prohibits the differentiation of Cuvier's beaked whale stock structure in the Gulf of Mexico from those in the Atlantic Ocean.

The status of Cuvier's beaked whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The Cuvier's beaked whale is distributed worldwide in deep offshore, tropical to cool temperate marine waters (Reeves et al. 2002). Species sightings in the northern GOM occurred primarily in the deep waters off the continental shelf.

Seasonal Distribution

Strandings of Cuvier's beaked whales have been recorded throughout the year in the northern GOM. During NMFS surveys, beaked whales were recorded in all seasons, but identifying the whales to the species level is difficult from aerial observations. Some of the aerial sightings may have been Cuvier's beaked whales.

Blainville's Beaked Whale (*Mesoplodon densirostris*)

Three species of the genus *Mesoplodon* have been recorded in the Gulf of Mexico, based on sightings and strandings. These are Blainville's beaked whale (*M. densirostris*), Gervais' beaked whale (*M. europaeus*), and Sowerby's beaked whale (*M. bidens*). The latter of these, Sowerby's beaked whale, is known in the Gulf from only one stranding record and is considered extralimital because of its typical range in the northern temperate waters of the North Atlantic. Identification of *Mesoplodon* species in the field is very difficult so these species are combined as beaked whales. This species grouping may also include some Cuvier's beaked whales that were not identified to species.

Status

The population of Blainville's beaked whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to

differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation and/or residency.

The status of Blainville's beaked whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends.. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The Blainville's beaked whale has widespread distribution in the tropical and warm temperate world oceans (Reeves et al. 2002). Sightings and stranding of this whale have been identified to the species level in the northern Gulf of Mexico. Beaked whale sightings in the Gulf have occurred primarily in the deep waters off the continental shelf.

Seasonal Distribution

Sightings of beaked whales have occurred in all seasons in the northern Gulf of Mexico during NMFS surveys.

Gervais' Beaked Whale (*Mesoplodon europaeus*)

Three species of the genus *Mesoplodon* have been recorded in the Gulf of Mexico, based on sightings and strandings. These are Blainville's beaked whale (*M. densirostris*), Gervais' beaked whale (*M. europaeus*), and Sowerby's beaked whale (*M. bidens*). The latter of these, Sowerby's beaked whale, is known in the Gulf from only one stranding record and is considered extralimital because of its typical range in the northern temperate waters of the North Atlantic. Identification of *Mesoplodon* species in the field is very difficult so these species are combined as beaked whales. This species grouping may also include some Cuvier's beaked whales that were not identified to species.

Status

The population of Gervais' beaked whales in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is no current information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation and/or residency.

The status of Gervais' beaked whales in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The Gervais' beaked whale appears to be distributed only in the tropical and warm temperate waters of the Atlantic Ocean (Reeves et al. 2002). Sightings and stranding of this whale have been identified to the species level in the northern Gulf of Mexico. Beaked whale sightings in the Gulf have occurred primarily in the deep waters off the continental shelf.

Seasonal Distribution

Sightings of beaked whales have occurred in all seasons in the northern Gulf of Mexico during NMFS surveys.

Bottlenose Dolphin (*Turisops truncatus*)

Status

Thirty-eight stocks of bottlenose dolphins are recognized by NMFS in the northern Gulf of Mexico for management purposes. These include 33 inshore stocks; 3 coastal stocks in the Eastern, Central and Western Gulf waters delineated as from the shore to 9 km seaward of the 10-fathom (18 m) contour; 1 outer continental shelf stock occurring from the coastal stock boundary to 9 km seaward of the 100-fathom (183 m) contour, and 1 continental shelf edge and slope stock occurring from the outer continental shelf boundary to the Exclusive Economic Zone (EEZ) boundary. These stocks may in fact overlap adjoining stocks in some areas and may be genetically indistinguishable from those stocks. The Gulf of Mexico bottlenose dolphin population consists of a coastal ecotype and an offshore ecotype.

The status of bottlenose dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends.. Both the oceanic and the continental shelf stocks are not considered strategic stocks because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR. However, the bay, sound and estuarine stocks (33) as well as the coastal stocks (3) are all considered strategic stocks due to documented cases of human mortality resulting in PBR being exceeded.

Distribution

Bottlenose dolphins are cosmopolitan marine mammals found in tropical and temperate oceans and peripheral seas. This species occupies a wide variety of habitats and is considered perhaps the most adaptable cetacean (Reeves et al. 2002). As shown by the numerous stocks mentioned above, this widespread species occurs throughout the Gulf of Mexico. Bottlenose dolphin habitat ranges from inshore bays and sounds to the deep waters of the continental slope. During NMFS oceanic surveys, bottlenose dolphins were seen primarily in water depths less than 1,000 m, and the highest density of this species was in northeastern Gulf slope waters (Mullin and Fulling, 2004). However, densities are similar between the eastern and western Gulf outer continental shelf waters. Bottlenose dolphins were also fairly evenly distributed between the coastal waters (< 20 m) and the outer continental shelf waters (20 to 200 m) (Fulling et al. 2003).

Seasonal Distribution

Sightings of bottlenose dolphins have occurred in all seasons in the northern GOM during NMFS surveys.

Atlantic Spotted Dolphin (*Stenella frontalis*)

Status

The population of Atlantic spotted dolphins in the Gulf of Mexico is being considered a separate stock for management purposes by NMFS. Recent information from Adams and Rosel (2005) suggested genetically this stock could be differentiated from North Atlantic stocks.

The status of Atlantic spotted dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. This is not a strategic stock because previous estimates of population size have been large compared to the number of cases of documented human-related mortality and serious injury.

Distribution

Atlantic spotted dolphins are one of two Gulf of Mexico dolphin species that occur only in the Atlantic Ocean (along with Clymene dolphins). Also, only this species and the bottlenose dolphin are commonly found in the shallower continental shelf waters (<200 m depth) of the Gulf (Mullin and Fulling, 2004). Atlantic spotted dolphins are primarily distributed in waters between 10 and 500 m in the

Gulf of Mexico and are not known to occur inshore. The density of Atlantic spotted dolphins is much greater in the eastern Gulf outer continental shelf waters than those of the western Gulf (Fulling et al. 2003).

Seasonal Distribution

Sightings of Atlantic spotted dolphins have occurred in all seasons in the northern GOM during NMFS surveys.

Pantropical Spotted Dolphin (*Stenella attenuatus*)

Status

The population of pantropical spotted dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, there is currently no information to differentiate this stock from the Atlantic stock(s). Additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of pantropical spotted dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

Pantropical spotted dolphins are found worldwide in all tropical to warm temperate waters between about 40°N and 40°S (Reeves et al. 2002). In the northern Gulf of Mexico, this species is widely distributed in deeper waters and is the most common cetacean in the oceanic northern GOM (Mullin et al. 2004; Wursig et al. 2000). The highest density for pantropical spotted dolphins is in the abyssal waters (> 2,000 m) but this species has been observed, though rarely, in the more shallow waters over the continental shelf (Mullin and Fulling, 2004).

Seasonal Distribution

Sightings of pantropical dolphins have occurred in all seasons in the northern GOM during NMFS surveys. However, Mullin and Fulling (2004) report that this species is two times more abundant in summer in the northeastern Gulf than in winter.

Striped Dolphin (*Stenella coeruleoalba*)

Status

The population of striped dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of striped dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The striped dolphin is cosmopolitan in distribution occurring in tropical and warm temperate waters (Reeves et al. 2002). In the northern Gulf of Mexico, sightings have occurred primarily in the deeper waters off the continental shelf (Mullin and Fulling, 2004).

Seasonal Distribution

Sightings of striped dolphins have occurred in all seasons in the northern GOM during NMFS surveys.

Spinner Dolphin (*Stenella longirostris*)

Status

The population of spinner dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of spinner dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

The spinner dolphin is distributed worldwide in temperate to tropical oceanic waters (Reeves et al. 2002). Sightings of spinner dolphins in the northern Gulf of Mexico have primarily occurred on the continental slope east of Mobile Bay (Mullin and Fulling, 2004).

Seasonal Distribution

Sightings of spinner dolphins have occurred in all seasons in the northern GOM during NMFS surveys.

Rough-toothed Dolphin (*Steno bredanensis*)

Status

The population of rough-toothed dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of rough-toothed dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. Despite an undetermined PBR, this is not a strategic stock because there is no documented human-related mortality and serious injury.

Distribution

The rough-toothed dolphin occurs in tropical and warm temperate waters globally (Reeves et al. 2002). In the northern Gulf of Mexico, sightings have occurred in both oceanic waters and in continental shelf waters (Fulling et al. 2003). This species may have a greater-than-expected presence in shelf waters (see Seasonal Distribution). Mullin and Fulling (2004) report that there may be similar numbers of rough-toothed dolphins in shelf waters as there are in oceanic waters.

Seasonal Distribution

Sightings of rough-toothed dolphins have occurred in all seasons in the northern GOM during NMFS surveys. Higher densities of rough-toothed dolphins were found in the fall in northern Gulf shelf waters than were found in oceanic waters in the spring (Fulling et al. 2003).

Clymene Dolphin (*Stenella clymene*)

Status

The population of clymene dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of clymene dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. The Gulf of Mexico stock is not a strategic stock because it is assumed that the average annual human-related mortality and serious injury does not exceed PBR.

Distribution

Clymene dolphins are found only in the deep tropical and subtropical waters of the Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea (Reeves et al. 2002). This is one of the two species commonly occurring in the Gulf that are endemic to the Atlantic. In the northern Gulf of Mexico, sightings have occurred primarily over the deeper waters off the continental shelf and mostly west of Mobile Bay (Mullin and Fulling, 2004).

Seasonal Distribution

Clymene dolphins were sighted in all seasons except fall in the northern Gulf of Mexico during NMFS surveys.

Fraser's Dolphin (*Lagenodelphis hosei*)

Status

The population of Fraser's dolphins in the Gulf of Mexico is provisionally being considered a separate stock for management purposes by NMFS. However, additional morphological, genetic, and/or behavioral data are required to confirm the Gulf stock delineation.

The status of Fraser's dolphins in the northern Gulf of Mexico is unknown (relative to the OSP). This species is not listed under the Endangered Species Act as threatened or endangered and insufficient data prohibits determination of population trends. Despite an undetermined PBR, this is not a strategic stock because there is no documented human-related mortality and serious injury.

Distribution

Fraser's dolphins are found worldwide in tropical waters, primarily in water depths greater than 1,000 m (Reeves et al. 2002). In the northern Gulf of Mexico, sightings have occurred primarily over the deeper waters off the continental shelf.

Seasonal Distribution

Sightings of Fraser's dolphins have occurred in all seasons in the northern GOM during NMFS surveys.

(5) 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;
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The BOEMRE requests NMFS to promulgate regulations for any potential take (level A or level B harassment) of 21 species of marine mammals (described in Section 4 above), incidental to conducting seismic survey operations, regulated by the BOEMRE, in the northern Gulf of Mexico OCS planning areas. The permitted operations, as described in Sections 1 and 2 of this application, have the potential to

take marine mammals by harassment as defined by NMFS. NMFS current criterion for the onset of level B harassment (behavioral disturbance) for cetaceans is exposure to 160-179 dB re 1 μ Pa rms for an impulse sound. The potential for incidental takes by level B harassment (probable risk of a behavioral response) during the use of airgun arrays is reasonably likely, thus warranting an authorization under section 101(a)(5)(A) of the MMPA.

Current NMFS policy is that the potential for permanent hearing damage (level A harassment – injury) for cetaceans exists at sound levels beginning at 180 dB re 1 μ Pa rms and greater. The potential for acoustic injury exists from the proposed action, as typical seismic sources will exceed 180 dB re 1 μ Pa rms close to the source. Since it remains unclear that the pulsed, low-frequency sound source resulting from airguns has actually caused injury to marine mammals in open water (National Research Council (NRC), 2003) or that marine mammals would not deflect away from sound intensities that could result in injury (MMS, 2004), the potential for injury is considered unlikely, but exposure to 180 dB re 1 μ Pa rms or greater is possible. Due to slow vessel speed, mortality or serious injury of healthy marine mammals by seismic vessels is unlikely.

(6) 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;

Anticipated takes as a result of seismic operation in the northern Gulf of Mexico OCS planning areas would be “takes by harassment” (Level B) mainly involving temporary changes in behavior. NMFS considers that take by harassment may occur at sound levels at or above 160 dB re 1 μ Pa (rms) for impulse sounds. This guideline does not consider the frequency component and nature of the sound source nor the hearing sensitivities of different cetacean species.

Similarly, at sound levels at or above 180 dB re 1 μ Pa (rms), NMFS has determined that the potential for physical damage to hearing exists. NMFS concluded in their June 29, 2007 Biological Opinion for the Five-Year Outer Continental Shelf Oil and Gas Leasing Program (2007-2012) in the Central and Western Planning Areas of the Gulf of Mexico that “the continued implementation of the impact minimization measures from seismic surveys in MMS’s NTL is expected to reduce this harassment and to prevent this harassment from resulting in actual loss of individual sperm whales.” The NTL referenced in this document is NTL 2007-G02 (*Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program*), and it requires shut-downs for all whales entering the exclusion zone. While these measures reduce the potential for injury, they do not entirely remove the possibility. Further, NTL 2007-G04 (*Vessel Strike Avoidance and Injured/Dead Protected Species Reporting*) implements requirements for vessel operations in the vicinity of protected species therefore reducing and minimizing the potential for injury or mortality from vessel strikes.

No lethal takes are anticipated under this proposed action given the implementation of required mitigation and monitoring measures. There is, however, the potential to expose some animals to sound levels exceeding 180 dB re 1 μ Pa (rms) which would in turn potentially allow for temporary or permanent loss of hearing. Permanent Threshold Shift (PTS) is defined as the deterioration of hearing due to prolonged or repeated exposure to sounds which accelerate the normal process of gradual hearing loss (Kryter, 1985), or the permanent hearing damage due to brief exposure to extremely high sound levels (Richardson et al. 1995). PTS results in a permanent elevation in hearing threshold—an unrecoverable reduction in hearing sensitivity (Southall et al. 2007). Temporary threshold shifts (TTS) indicate a temporary and reversible loss of hearing that may last for minutes to hours. The duration of TTS depends on a variety of factors including intensity and duration of the stimulus. Therefore, animals suffering from TTS over longer time periods, such as hours or days, may be considered to have a change in a biologically significant behavior, as they could be prevented from detecting sounds that are biologically relevant, including communication sounds, sounds of prey, or sounds of predators.

BOEMRE anticipates any risks for PTS (Level A harassment) or TTS (i.e., Level B harassment) from seismic survey sound exposure, although possible, are likely minimized given:

- the implementation of mitigation and monitoring measures expanded from that required under NTL 2007-G02 (e.g., establishment of an exclusion zone, shutdowns, protected species observer program) which are designed to avoid large whale (as low or mid frequency specialists have hearing ranges with the greater potential for overlap with seismic noise) exposure to sound levels equal to or greater than 180 dB re 1 μ Pa (rms)
- the most recent scientific information (Southall et al, 2007) estimates the actual onset for acoustic injury from multi-pulse sources (i.e., seismic survey sound sources) to be 230 dB re 1 μ Pa (flat) rather than 180 dB re 1 μ Pa (rms);
- the required mitigation and monitoring measures, based on avoiding sound exposure levels of greater than 180 dB re 1 μ Pa (rms), are therefore considered conservative.

The number of marine mammals, by species, estimated to be exposed to these “take thresholds” has been calculated for seismic activities using best available data and assumptions as outlined below and provided in detail in Appendix A (MAI, 2010) of this request. Because of numerous data limitations and uncertainties in assessing acoustic effects on cetaceans, the best estimate of marine mammal density for a geographic location is used to predict a possible number of animals within a given distance of a sound source. Those animals within calculated isopleths of sound above 160 dB re 1 μ Pa (rms) are considered a take. This basic rationale (independent of uncertainties in numbers) probably overestimates actual take numbers (exposure of an animal to a sound is not necessarily equivalent to the animal being taken).

The basic data elements used to estimate incidental take include: summary of seismic survey activity levels derived from recent BOEMRE survey records, estimates of future effort from the seismic industry and the best available marine mammal density estimates for the GOM based on the Navy OPAREA Density Estimates (NODE) database (DoN, 2007b) (which were derived from the NMFS-SEFSC shipboard surveys conducted between 1994 and 2006). Take estimates for each of the five types of seismic activity (OBS, 2-D, 3-D, WAZ, and 2-D High Resolution) have been divided into nine basic areas based on shallow (< 200 m depth), slope (200-1000 m) and deep water (\geq 1000 m) portions of the three OCS planning areas of the Gulf of Mexico (western-WPA, Central-CPA, Eastern-EPA) (see Figure 2-1).

Due to the large number of surveys and survey types in the GOM, precise calculations associated with specific airgun arrays are impractical. Nor is it possible to develop a projection of exactly what distribution of possible arrays will be used in the future. Instead, a “typical deep seismic array” has been defined based on an analysis of airguns utilized in Gulf of Mexico operations. The defined array is a 4,550-in³ airgun array with a 240 dB zero to peak and 230 dB rms. Actual array output varies by seismic survey type and can be considerably higher or lower depending on the number of arrays and airguns used. This could result in an increase or decrease of the ensonification area. In non-commercial operations, array size can vary and be considerably larger, such as the Lamont-Doherty Earth Observatory’s 6,600 in³ 36-gun array used on the R/V *Marcus G. Langseth* (Tolstoy et al. 2009).

It is known that a seismic signal is comprised primarily of low-frequency components with a peak of 50- 60 Hz, but also has contributions from both mid- and high-frequency components. It is also known that the area of ensonification, when viewed from above is a somewhat irregular isopleth when actually measured but more closely approximates an elliptical shape rather than a circle (MMS, 2004). Take estimates for each marine mammal species were calculated using the AIM model (see Appendix A for details) and then incorporating both NMFS standard thresholds as well as Level A thresholds from the findings in Southall et al. (2007).

Using detailed modeling of the source and its properties, the acoustic propagation field in three dimensions, and three dimensional animal placement and movement to better calculate the potential impacts to marine mammals take estimates were calculated for each species. This included different types of seismic activity with differing sources levels, different water depths (shallow, slope, and deep) and different OCS planning areas. For this methodology, the first step is largely controlled by properties of the source, such as its movement in time and space, and the sound field it generates at any point in time. Propagation modeling further analyzes the effects of the physical properties of the ocean, the bottom and the surface on the sound field as it propagates out from the source. The second step requires knowledge of the diving and movement characteristics of the animals residing in the exposed region. Time-based integration models, such as the Acoustic Integration Model[®] (AIM) developed by Marine Acoustics, Inc., as used in this modeling effort, are necessary to fully evaluate the exposure. AIM is a

software package developed to predict the acoustic exposure of marine animals from an underwater sound source. The unique and principal component of AIM is a 3-D movement engine, which programs the geographic and vertical movements of sound sources and simulated marine animals. In this MMPA application, BOEMRE is providing Level A and Level B harassment take estimates using AIM and incorporating both standard Level A harassment (Table 6-1) as well as Level A using Southall et al. (2007) (Table 6-2). For Level B harassment, BOEMRE is using the 160 dB that has been standard for NMFS. BOEMRE believes that using AIM, including Southall et al. (2007) is based on the best scientific information available.

In 2006, the Center for Independent Experts (CIE) conducted a review and assessment of AIM. The CIE panel concluded that AIM is a credible tool for developing application models (Independent System for Peer Review 2006). The advantage of these tools is that they not only provide a more accurate and detailed model of the exposures of a population of marine animals in the three dimensions and time, but they also provide: 1) statistical data on each individually modeled animal and the population as a whole; 2) rate of exposure (sounds per unit time) over the duration of a survey; and 3) the data necessary to determine effects based on more sophisticated thresholds, such as sound exposure level, SEL.

Table 6-1. Estimates of Potential Level A and B Harassment Impacts Using AIM Methodology and Standard Thresholds.

Marine Mammal Species	Level A (180 dB)						Level B (160 dB)					
	2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
<i>Mysticetes</i>												
Bryde's whale	2.1	1.9	2.0	2.1	0.03	0.03	60.4	42.0	12.8	21.7	118.1	100.1
<i>Odontocetes</i>												
Atlantic spotted dolphin	6647.8	1984.1	282.9	1007.0	9841.7	8034.4	126106.7	35502.2	4394.8	17996.7	182775.1	149084.9
Beaked whales:	77.5	66.7	16.3	29.8	159.1	132.1	1870.5	1434.4	443.0	751.2	3745.4	3184.4
Cuvier's												
Blaineville's												
Gervias'												
Bottlenose dolphin	27925.6	11629.0	1787.0	6229.0	58691.6	47999.2	265774.6	118531.9	26384.7	63431.7	460514.0	379802.9
Clymene dolphin	3109.1	2541.3	771.7	1273.6	6190.4	5257.8	24927.4	17229.8	4301.4	8025.3	49496.3	41423.1
False Killer whale	215.3	176.1	46.5	82.4	442.6	372.3	2635.2	2043.2	676.6	1084.1	5117.4	4383.0
Fraser's dolphin	162.7	130.3	40.4	65.4	323.1	274.5	1460.3	1019.0	308.4	524.7	2831.6	2401.1
Killer whale	820.3	322.1	78.4	167.5	1119.8	928.2	21418.8	7891.6	1628.0	3944.1	29273.6	24126.7
Kogia spp.	266.0	271.6	77.1	124.7	532.3	453.8	1336.3	1280.3	502.9	728.0	2399.1	2119.6
Dwarf sperm whale												
Pygmy sperm whale												
Melonheaded whale	754.8	614.1	158.1	283.4	1555.4	1306.1	8849.5	6811.8	2252.7	3613.8	17122.8	14659.7
Pantropical spotted dolphin	25073.7	18969.7	5523.1	9816.7	51802.1	43606.2	215647.6	148395.2	39765.9	76291.2	441142.2	367083.6
Pygmy killer whale	85.5	72.7	19.7	34.0	176.9	148.9	990.7	762.4	250.7	400.7	1922.9	1649.1
Risso's dolphin	1280.0	828.0	190.8	404.8	2716.9	2246.6	9687.2	6199.2	1853.9	3432.2	19862.9	16684.0
Rough-toothed dolphin	987.8	655.6	129.1	290.1	2030.8	1681.9	9840.8	7226.6	1970.8	3431.7	18032.3	15251.0
Short-finned pilot whale	442.7	372.3	101.3	173.7	900.9	760.0	6115.1	4689.3	1530.4	2469.7	11921.1	10201.7
Sperm whale	217.1	167.7	52.0	90.3	442.6	372.3	2377.2	1833.5	605.6	979.6	4684.7	4015.7
Spinner dolphin	4643.3	3273.3	1202.6	1975.6	8762.5	7466.9	68655.0	34767.6	8648.8	19246.0	139045.2	115052.4
Striped dolphin	5458.3	1924.1	683.2	1100.1	4122.8	3550.9	19240.6	12572.3	3592.8	6600.5	38143.7	31999.1

Table 6-2. Estimates of Potential Level A and B Harassment Impacts Using AIM and Historic Thresholds with Southall et al (2007) Applied.

Marine Mammal Species	Level A (SPL-230, SEL-215 dB)						Level B (160 dB)					
	2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
<i>Mysticetes</i>												
Bryde's whale	0.02	0.03	0.03	0.03	0.03	0.03	60.4	42.0	12.8	21.7	118.1	100.1
<i>Odontocetes</i>												
Atlantic spotted dolphin	69.6	49.3	19.1	23.2	123.4	100.9	126106.7	35502.2	4394.8	17996.7	182775.1	149084.9
Beaked whales:	0.1	0.1	0.1	0.1	0.1	0.1	1870.5	1434.4	443.0	751.2	3745.4	3184.4
Cuvier's												
Blaineville's												
Gervias'												
Bottlenose dolphin	1010.2	426.2	65.9	234.8	2182.5	1785.8	265774.6	118531.9	26384.7	63431.7	460514.0	379802.9
Clymene dolphin	278.1	224.6	67.3	109.0	539.2	460.8	24927.4	17229.8	4301.4	8025.3	49496.3	41423.1
False Killer whale	3.2	2.6	3.0	3.0	2.5	3.4	2635.2	2043.2	676.6	1084.1	5117.4	4383.0
Fraser's dolphin	2.9	2.7	2.9	3.1	2.8	3.6	1460.3	1019.0	308.4	524.7	2831.6	2401.1
Killer whale	32.0	11.5	1.0	4.6	45.7	37.4	21418.8	7891.6	1628.0	3944.1	29273.6	24126.7
Kogia spp.	0.8	0.5	0.7	0.6	0.4	0.7	1336.3	1280.3	502.9	728.0	2399.1	2119.6
Dwarf sperm whale												
Pygmy sperm whale												
Melonheaded whale	12.6	17.2	12.3	12.8	10.8	13.1	8849.5	6811.8	2252.7	3613.8	17122.8	14659.7
Pantropical spotted dolphin	1045.9	864.7	365.0	520.2	1835.1	1609.2	215647.6	148395.2	39765.9	76291.2	441142.2	367083.6
Pygmy killer whale	1.0	0.7	0.9	0.8	0.6	0.9	990.7	762.4	250.7	400.7	1922.9	1649.1
Risso's dolphin	1.7	1.6	1.7	1.5	1.4	1.6	9687.2	6199.2	1853.9	3432.2	19862.9	16684.0
Rough-toothed dolphin	1.9	2.0	1.5	1.7	1.6	1.4	9840.8	7226.6	1970.8	3431.7	18032.3	15251.0
Short-finned pilot whale	7.6	9.3	7.4	7.4	6.1	8.3	6115.1	4689.3	1530.4	2469.7	11921.1	10201.7
Sperm whale	19.1	13.9	3.6	6.8	40.7	33.8	2377.2	1833.5	605.6	979.6	4684.7	4015.7
Spinner dolphin	394.1	256.1	69.7	132.8	782.0	650.5	68655.0	34767.6	8648.8	19246.0	139045.2	115052.4
Striped dolphin	189.4	162.4	53.0	83.6	356.6	305.8	19240.6	12572.3	3592.8	6600.5	38143.7	31999.1

(7) The Anticipated Impact of the Activity Upon the Species or Stock;

The potential effects of noise on marine mammals can be either behavioral or physiological or both (For more information see Gordon et al. 2003, references therein and MMS (2004)). Of the 21 species of cetaceans found regularly occurring in the Gulf of Mexico, only one, the Bryde's whale (*Balaenoptera edeni*), makes low-frequency vocalizations, while all others vocalize in the mid-frequency range. The potential impacts of seismic surveys on mysticetes and odontocetes are discussed below.

Mysticetes

The only commonly occurring baleen whale in the northern Gulf of Mexico is the Bryde's whale (*Balaenoptera edeni*). Baleen whale hearing sensitivity overlaps with maximal seismic airgun output. This puts them at greatest risk of auditory impacts from seismic sounds as many of their vocalizations overlap the maximum frequency range of energy output of a typical airgun array. Potential impacts include auditory impacts (hearing loss, injury, and discomfort), masking of important low-frequency sounds (communication, etc.) and changes in behavior are all possible as a result of seismic sounds.

Although there have been no studies of the reaction of Bryde's whale to seismic activities, it is generally considered that the auditory abilities of all mysticete species are broadly similar, based upon vocalization frequencies and ear anatomy (Ketten, 1998). Limited data on Bryde's whale reactions to other anthropogenic disturbances suggest little response to slowly approaching boats (Watkins, 1981), and that this species, like others, also appears to be easier to approach when feeding (Gallardo et al. 1983).

The synthesis of the behavioral response studies on mysticete whales indicates that the onset of significant behavioral disturbances from seismic-generated noise for migrating bowhead whales occurs at received levels (RMS over pulse duration) of ~120 dB re 1 μ Pa, while gray, blue, humpback, and feeding bowhead whales experience onset around 150 to 160 dB re 1 μ Pa (Southall et al. 2007). Bowhead whales exhibited responses to seismic airguns that included an avoidance response, at distances as great as 20 km around seismic surveying (where received levels were estimated to be approximately 117-135 dB re 1 μ Pa rms (Richardson et al. (1999), as well as changes in swimming and breathing (Richardson et al. 1986, 1999; Ljungblad et al. 1988), although feeding bowheads did not exhibit avoidance responses even when airguns were as close as 6 km (Miller et al. 2005). Malme et al. (1983, 1984) found that migrating gray whales exhibit avoidance responses to received levels greater than 160 dB re 1 μ Pa. Those gray whales that reacted generally slowed, turned away from the noise source, and increased their respiration rates (Richardson et al. 1995). For migrating humpback whales, an avoidance response begins at ~150 dB re 1 μ Pa (peak-to-peak) while general avoidance occurs at ~168 dB re 1 μ Pa (peak-to-peak) (McCauley et al. 1998). McDonald et al. (1995) observed that blue whales stopped vocalizing at an estimated 143 dB re 1 μ Pa (peak-to-peak) received level that occurred about 10 km from the seismic vessel and changed course to avoid closing on the seismic vessel.

The other baleen whales that have been sighted in the GOM are either considered rare or extralimital by Waring et al. (2009). These are the northern right whale, minke whale, sei whale, blue whale, fin whale, and humpback whale. If individuals of any of these species are sighted, special mitigation measures would apply due to their rarity and sensitivity. Airgun arrays would be shut down (not just powered down) if any of these species is sighted from the vessel. In case of confirmed sightings of any of these species, airgun operations would not resume until 30 min after the last documented whale visual sighting and the protected species observer (PSO) is confident that the whale is no longer in the vicinity of the vessel.

Odontocetes

There are a large number of odontocete species in the GOM. Their hearing thresholds are highly varied and species-specific. Many of these species are sensitive to high frequency sounds due to their use of high frequency sound pulses for echolocation and communication. Their sensitivity to low frequency sounds appears to be relatively poor, though low frequency hearing has not been extensively studied in

odontocetes. Seismic sounds are predominately low frequency (<200 Hz), though airgun arrays also produce energy at higher frequencies that may negatively impact some delphinid species. Potential impacts include auditory impacts (hearing loss, injury, and discomfort) as well as modification of some behaviors (avoidance, vocalizations).

Only a limited number of studies have been conducted on behavioral responses of odontocetes to seismic noise. Sperm whale behavioral responses have been the best studied of the odontocetes, although limited work on dolphin and beluga whales has also been conducted. The available data on odontocete behavioral responses to the underwater noise generated by seismic airguns and arrays, even for the same species, do not indicate clear response patterns. For instance, low received levels (~80 to 90 dB re 1 μ Pa) temporarily caused sperm whales to stop vocalizing, while received levels of 120 to 180 dB re 1 μ Pa did not cause noticeable behavioral reactions from sperm whales (Southall et al. 2007).

Sperm Whales

There is a reasonable potential that seismic surveys are exposing sperm whales to noise levels that may cause behavioral disturbance. The most probable disturbance is whales avoiding (moving away from) a seismic vessel. The degree of displacement, length of time involved, and types of normal activities interrupted would influence the significance of this disturbance. Less likely, but possible, are sperm whales remaining within acoustic exposure levels that will cause temporary hearing impairment or permanent hearing damage. This outcome would require whales to lack the ability to detect harmful sound intensities, “ignore” the signal in favor of other behavior such as feeding, or be in close proximity to a sudden start-up of airguns. The environment is deep, open waters. Short of a physically impaired whale, no physical constraints to “trap” a whale near a seismic sound source exist. Mitigation measures now in place remove sudden start-up as a possibility and observers with shut-down procedures substantially reduce the possibility of intense exposures. However, a deep-diving whale could be exposed to >180 dB signal intensities if the airgun array passes over the whale and the whale does not respond to (avoid) the increasing intensity.

There is an apparent concentration of whales located on the continental slope offshore of the Mississippi River mouth (and extending east to the DeSoto Canyon area in the Eastern Planning Area). Although sperm whales apparently are not being displaced from this area because of seismic surveys, it is unknown whether their site fidelity reflects low sensitivity to seismic noise or a high motivation to remain in the area in spite of this noise. Weir (2008) found few obvious visible responses of sperm (and humpback) whales to seismic airgun sounds off Angola, however only overt responses were examined.

From 2002-2005, BOEMRE funded a multi-year, interdisciplinary study on sperm whales in the GOM, called the Sperm Whale Seismic Study (SWSS). A summary report (OCS Study, MMS 2006-034) was produced in 2006 (Jochens et al. 2006), and a synthesis report (OCS Study, MMS 2008-006) was released in 2008 (Jochens et al. 2008). These reports provide the following conclusions regarding sperm whales in the GOM and their response to seismic surveys:

- During controlled exposure experiments (CEEs), researchers could detect “no horizontal avoidance of the seismic source for exposure levels (RLs) of <150 dB re 1 μ Pa (rms).” Similarly, opportunistic studies detected no apparent horizontal avoidance or displacement of sperm whales associated with operational seismic surveys;
- The CEE data results do not support the assumption that whales swim away from an airgun as it ramps up or approaches the whale at full power;
- In contrast to the lack of avoidance response, the CEE results showed there may be statistically significant changes in the swimming and foraging behavior of sperm whales exposed to the sound of airguns in the exposure range (RL) of 111 to 147 dB re 1 μ Pa (rms) (131 to 164 dB re 1 μ Pa [peak to peak]; see Table I in Madsen et al. 2006) at distances of approximately 1.4 – 12.6 km from the sound source; and
- There was the “discovery of a statistically significant 60% reduction in foraging for one whale coupled with evidence that other whales are less sensitive...”

(8) The Anticipated Impact of the Activity on the Availability of the Species or Stocks of Marine Mammals for Subsistence Uses;

Not applicable - There are no subsistence uses of marine mammals in the northern Gulf of Mexico.

(9) The Anticipated Impact of the Activity Upon the Habitat of the Marine Mammal Populations, and the Likelihood of Restoration of the Affected Habitat;

The majority of seismic operations anticipated will involve no more than a passing vessel introducing an elevated sound level into the water column. Adjacent areas may be exposed to pulsed sound over several days during the course of a survey; however, a continuous repetition of seismic operations in the same local habitat over months or years does not typically occur. No lasting modification or alteration of the habitat will occur. Immediate avoidance of the vessel (short-term, local displacement) may occur, but this situation does not represent loss of habitat.

There is no residual chemical or physical alteration of the habitat. The intensity of seismic sound sources would most likely injure or kill small organisms within a meter or so of an airgun or airgun array. Hearing damage to fish and, more so, behavioral alterations can occur in extended radii surrounding the sound source, likely on the same order as potential Level B takes at 160 dB re 1 μ Pa (rms) (LGL, 2003).

Habitat impacts, at most, will be some possible injurious effects on fish and planktonic organisms in close proximity to an airgun array and a greater area of possible behavioral responses. These are short-term impacts. Alteration of the habitat is minimal; restoration of the affected habitat to a pre-seismic state is rapid.

One exception to this type of operation would be proposed “4-D” survey using either fixed nodes/cables or repeated seismic surveys conducted over months to years. Some local benthic disturbance resulting from laying of nodes or cables. A negligible disturbance of sediments and benthic organisms will occur in these instances.

Even in this case, “repeated seismic operations” represent a geographically local area on the order of one lease block at most, and repetition is on the order of several days of firing airguns separated by several weeks to months of no activity.

(10) The Anticipated Impact of the Loss or Modification of the Habitat on the Marine Mammal Populations Involved;

Beyond a possible immediate, local avoidance of seismic operations, no habitat loss or modification is anticipated. Studies of the effects of seismic surveys have focused almost exclusively on the effects on individual species or related groups of species, with little attention being given to broader community-level issues. Parente et al. (2007) suggested that the diversity of cetaceans near the Brazil coast was reduced during years with seismic surveys. However, a preliminary account of a more recent analysis suggests that the trend did not persist when additional years were considered (Britto and Silva Barreto 2009). There are no anticipated impacts to marine mammal populations through loss or modification of habitat.

(11) 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;

The current mitigation suite, which is effective in all Federal waters in the Eastern Planning Area and in Federal waters >200 m depth in the Central and Western Planning Areas, includes ramp-up, visual monitoring by trained observers, establishment of an impact zone (currently 500 m around the sound source), and mandatory “shut-down” to avoid injury to large whales in or about to enter the impact zone. Detailed descriptions of mitigations are provided in [NTL 2007-G02](#) and this is attached as an Appendix to this application. Each of these helps ensure the least practicable adverse impact for certain marine mammal species. Ramp-up, or soft start, requires seismic operators to start firing the acoustic array with one gun and gradually over time add more guns until the array is fully operational. This allows cetaceans

in the area to move away from the sound source before discomfort or injury might result. Visual observers monitor the area around the sound source for 30 minutes prior to ramp-up and throughout seismic operations. Any time a whale enters or surfaces within 500 m of the sound source, seismic transmissions are immediately ceased in order to minimize as much as possible the exposure of the whales to potentially damaging levels of sound. A protected species observer program is currently in place requiring trained observers on all seismic vessels. Enhanced monitoring and reporting is also required under the latest seismic NTL. Again, for more detail on mitigations currently in effect, please see [BOEMRE Notice to Lessees NTL 2007-G02](#).

Although not presently required, but encouraged under the NTL, the voluntary use of passive acoustic monitoring (PAM) is becoming more common. Using PAM in an operational setting allows 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. Research during the Sperm Whale Seismic Study (SWSS) also provided recommendations for improved PAM technology in the GOM. In November of 2009, BOEMRE hosted a workshop “*Status and Applications of Acoustic Mitigation and Monitoring Systems for Marine Mammals*.” This workshop focused on the capabilities, applicability, feasibility and availability of current acoustic monitoring systems. The presentations and background materials can be found at: <http://www.acousticmonitoring.org/index.html> and the complete proceedings will be available in the next few months.

Alternative technologies could be used to minimize or reduce the amount of sound introduced into the marine environment during seismic surveys. Methods of either reducing sound from existing technology as well as new alternatives to airguns are discussed in detail in symposia from a recently held workshop “[Alternative Technologies to Seismic Airgun Surveys for Oil and Gas Exploration and their Potential for Reducing Impacts on Marine Mammals](#)” Weilgart (2010). Participants in this 2009 workshop examined quieter, potentially less harmful technologies that might be able to, at least partially, replace airguns. Technologies discussed included controlled source electromagnetics, marine vibrators, and modifications to existing airgun technologies to reduce unwanted energy.

(12) 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 affects on the availability of marine mammals for subsistence uses;

Not applicable - There are no subsistence uses of marine mammals in the northern Gulf of Mexico.

(13) 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;

Current monitoring and reporting requirements are set forth in BOEMRE’s Notice to Lessees and Operators of Federal Oil, Gas, and Sulphur Leases in the Outer Continental Shelf, Gulf of Mexico OCS Region (NTL 2007-G02): *Implementation of Seismic Survey Mitigation Measures and Protected Species Observer Program*. The NTL applies to seismic surveys in all water depths in the Eastern Planning Area of the GOM and in water depths greater than 200 m in the rest of the GOM. Reporting is required from all working seismic vessels in the GOM on a bi-weekly basis. Sightings are reported on the 1st and 15th of each month, and any shut-downs must be reported to BOEMRE within 24 hours.

An annual report summarizing all sperm whale and sea turtle sightings is submitted by BOEMRE to the National Marine Fisheries Service (NOAA Fisheries) Southeast Regional Office. This reporting requirement was made as part of the conservation recommendations in NMFS’ Biological Opinion (August 30, 2003) for the Gulf of Mexico Outer Continental Shelf Oil and Gas Lease Sales 189 and 197.

Monitoring during seismic surveys requires visually-oriented Protected Species Observers (PSOs). At least two protected species visual observers are required on watch aboard seismic vessels at all times during daylight hours (nautical twilight-dawn to nautical twilight-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 must resume as soon as conditions permit. Operators currently may engage trained third party observers, may utilize crew members after training as observers, or may use a combination of both third party and crew observers. During these observations, the following guidelines shall be followed: (1) other than brief alerts to bridge personnel of maritime hazards, no additional duties may be assigned to the observer during his/her visual observation watch (if conditions warrant more vigilant look-outs when navigating around or near maritime hazards, additional personnel must be used to ensure that watching for protected species remains the primary focus of the on-watch observers), (2) no observer will be allowed more than 4 consecutive hours on watch as a visual observer, (3) a “break” time of no less than 2 hours must be allowed before an observer begins another visual monitoring watch rotation (break time means no assigned observational duties), and (4) no person (crew or third party) on watch as a visual observer will be assigned a combined watch schedule of more than 12 hours in a 24-hour period. Due to the concentration and diligence required during visual observation watches, operators who choose to use trained crew members in these positions are encouraged to select only those crew members who demonstrate willingness as well as ability to perform these duties.

All visual observers must have completed a protected species observer training course. The BOEMRE does not sanction particular trainers or training programs. However, basic training criteria have been established and must be adhered to by any entity that offers observer training (NTL 2007-G02). Operators may utilize observers trained by third parties, may send crew for training conducted by third parties, or may develop their own training program.

Visual Monitoring Methods

The observers on duty will look for whales, other marine mammals, and sea turtles using the naked eye and hand-held binoculars. 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° coverage surrounding the seismic vessel and will adjust their positions appropriately to ensure adequate coverage of the entire area. These observations must be consistent, diligent, and free of distractions for the duration of the watch.

Visual monitoring will begin no less than 30 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 a marine mammal (whale or dolphin) or sea turtle is observed, the observer should note and monitor the position (including lat./long. of vessel and relative bearing and estimated distance to the animal) until the animal dives or moves out of visual range of the observer. Make sure to continue to observe 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 whale is observed within an estimated 500 m of the sound source array (“exclusion zone”), whether because of the whale’s movement, the vessel’s movement, or because the whale surfaced inside the exclusion zone, the observer will call for the immediate shut-down of the seismic operation and airgun firing (the vessel may continue on its course but all airgun discharges must cease). The vessel operator must comply immediately with such a call by an on-watch visual observer. Any disagreement or discussion should occur only after shut-down. When no whales are sighted for at least a 30-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 whales for 30 minutes prior to commencement of ramp-up (unless the method described in the section entitled “Experimental Passive Acoustic Monitoring” is used). Thus, ramp-up cannot begin after dark or in conditions that prohibit visual inspection (fog, rain, etc.) of the exclusion zone. Any shut-down caused by a whale(s) sighting within the exclusion zone must be followed by a 30-minute all-clear period and then a standard, full ramp-up. Any shut-down 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 whales, other marine mammals, or sea turtles are observed in the exclusion zone. If whales, other marine mammals, or sea

turtles are observed in the exclusion zone during the short silent period, resumption of seismic survey operations must be preceded by ramp-up.

Experimental Passive Acoustic Monitoring

Whales, especially sperm whales, are very vocal marine mammals, and 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 may be at greatest risk of potential injury from seismic airguns when they are submerged and under the airgun array. Passive acoustic monitoring appears 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 BOEMRE strongly encourages seismic operators to participate in an experimental program by including passive acoustic monitoring as part of the protected species observer program. Inclusion of passive acoustic monitoring does not relieve an operator of any of the mitigations (including visual observations) in the NTL with the following exception: Monitoring for whales 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. If passive acoustic monitoring is used you must include an assessment of the usefulness, effectiveness, and problems encountered with the use of the method of marine mammal detection in the reports described in the NTL.

Reporting

Three reports are submitted on the 1st and the 15th of each month: observer effort, survey, and sighting reports. The observer effort report is prepared for each day during seismic operations and includes information about when visual surveys were conducted as well as the average environmental conditions during the surveys. Survey reports (also prepared daily) include information about ramp-up activities, marine mammal observations made during ramp-up activities, and the duration and intensity of airgun activity. Sighting reports are made only when a marine mammal or sea turtle is observed. Data include the species observed, number of individuals (including juveniles), the animal's behavior (noting any observed changes), closest distance of the animal(s) to the airguns, and whether or not the airguns were firing at the time of the observation. In the event that the sighting was of a whale(s) within the exclusion zone that resulted in a shut-down of the airguns, the report must include the observed behavior of the whale(s) before shut-down, the observed behavior following shut-down (specifically noting any change in behavior), and the length of time between shut-down and subsequent ramp-up to resume the seismic survey (note if seismic survey was not resumed as soon as possible following shutdown). The report is sent to BOEMRE within 24 hours of the shut-down.

(14) Suggested Means of Learning of, Encouraging, and Coordinating Research Opportunities, Plans, and Activities Relating to Reducing Such Incidental Taking and Evaluating Its Effects.

The BOEMRE has long taken a lead in evaluating the potential effects of industry related noise on marine mammals. Beginning in the mid-1970's, BOEMRE (then Bureau of Land Management) contracted for studies on the effects of noise on marine mammals in the Alaska and Pacific OCS Regions. In 1987, BOEMRE (then MMS) awarded a contract to LGL Ltd to prepare a comprehensive review of all literature with emphasis on the effects of noise from oil industry activities. In 1992, the Office of Naval Research (ONR) agreed to provide core funding to convert the MMS report into an expanded manuscript suitable for commercial publication. "*Marine Mammals and Noise*" by Richardson et al. (1995) was published by Academic Press through ONR and MMS/BOEMRE funding support.

In 1999, MMS funded a workshop on protected species issues in the Gulf of Mexico (McKay et al. 2001). Following presentations on issues, comments from a panel of eight experts, and public comment, a post-workshop meeting was held with the expert panel and other Federal representatives to discuss research priorities. One outcome, based on strong and clear recommendations for the workshop experts, was to modify an existing agreement with NMFS to conduct cetacean surveys to also explore methods to study acoustic impacts with the emphasis on effects of airguns on sperm whales. The Sperm Whale Acoustic Monitoring Program (SWAMP) began in June 2000 with joint support from MMS, ONR, and NMFS. The two-year pilot program effectively established new methods to study acoustic impacts and baseline whale behavior, including use of digital tags (D-tags), satellite tags (S-tags), passive acoustics,

and team coordination to effectively track whales through visual and acoustic methods, and direct small boats to tag whales.

With success on developing tools and methods, a directed study to evaluate the effects of seismic operations on sperm whales began in 2002. The Sperm Whale Seismic Study (SWSS) included support from BOEMRE, Office of Naval Research, National Science Foundation (NSF), and a coalition of seismic and oil industry funders. The SWSS further coordinated with related industry research in initiatives and ongoing NMFS Gulf of Mexico cetacean surveys co-funded by the Navy (N-45). Further, BOEMRE has supported acoustic research through the National Oceanographic Partnership Program (NOPP).

Field work for SWSS was completed in 2005 and a final synthesis report was produced in 2008 ([MMS 2008-006](#)). Recommendations from this project included continued data collection of basic population biology parameters including breeding/calving, feeding and foraging and prey species identification. In 2009, BOEMRE through an interagency agreement with NMFS began the Sperm Whale Acoustic Prey Study (SWAPS) which will characterize the prey base for sperm whales in the GOM.

Of key interest for research is the controlled exposure experiment (CEE) approach in which cetaceans are intentionally exposed to a sound source (airguns in this case) and animal response/exposure level measured by attached digital-tags. This approach would lead to relatively precise estimates of behavioral changes in swimming, diving, and vocalizations correlated to measured received sound level. A debate remains on if these data are “worth” some degree of risk with intentional exposures.

Another approach BOEMRE and partners are pursuing is to actively monitor the existing situation in the GOM. All seismic vessels subject to BOEMRE permitting now provide observer reports as part of mitigation and monitoring requirements. These data can be integrated into an overall research evaluation of seismic effects. BOEMRE, through the Environmental Studies program, is working with a contractor to analyze data from the seismic observer reporting and a final report is expected in 2011. SWSS developed improved passive acoustic monitoring techniques — ultimately to predict the bearing and range of submerged sperm whales. This methodology can be transferred to mitigation detection applications and/or a research vessel can provide enhanced observations of ongoing seismic surveys. Improved satellite location tags with time depth recording (TDR) capacity -can provide diving depths and precise (GPS) surfacing locations over months to a year. A limited number of sperm whales could be tagged in advance of seismic operations and their movements correlated with vessel operations over extended times — in a sense, uncontrolled exposure experiments.

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APPENDIX A¹

ACOUSTIC MODELING APPROACH AND METHODOLOGY

¹This document was prepared by Marine Acoustics, Inc. under contract to the National Marine Fisheries Service (Contract: GS-10F-0164N; Order: DG133F06NC2020) for use in the preparation of the *Draft Programmatic Environmental Impact Statement for the Geological and Geophysical Exploration of Mineral and Energy Resources in the Gulf of Mexico*.

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1.0 INTRODUCTION

1.1 OVERVIEW

The purpose of this appendix is to document the overall approach and to identify the specific model, acoustic source, environmental and biological data and modeling techniques used to calculate the potential acoustic impacts of the proposed actions, which are presented in Chapter 4 of this PEIS. The general philosophy used in determining these estimates was that “reasonably” representative values be employed when the calculations were made. This approach is based on the knowledge that an exact predictive modeling of: a) exactly which source would be employed at each site, b) the exact environmental acoustics conditions at each site, c) the timing of each survey, and d) the marine animals present at each site of source operations, could not be known at any given time (without extensive surveys immediately prior to or during the survey) and particularly not for the period of this document (i.e., the next five years). The “reasonable” approach described in this appendix, in general, examined the potential range of each variable and identified what were typically used or expected to be used during execution of the proposed action. In some situations, even the extreme range of variable values had minimal affect on the results, or the low occurrence of some of the values in the range allowed an obvious selection for modeling. For example, nearly all of the deep-water sites had very fine silts, clayey silt and clay as the predominant bottom types and clay’s characteristics were used when modeling the acoustic propagation in those sites, since the bottom properties of the other sediments were very similar. However, in the case of the airgun source used for modeling, there are numerous possible source arrays that could be used based on the company performing the survey, the location, the ships available, etc. Here, the source identified by industry and the Bureau of Offshore Energy Management, Regulation, and Enforcement (BOEM; previously Minerals Management Service (MMS) of the U.S. Department of the Interior) as a typical source for these surveys, was used in the modeling. And even though it is not the strongest source identified, it better represents a typical source array and its potential impacts. Also, it is estimated that the percentage of time that strong and weaker sources are used over the duration of the proposed action will only slightly change the overall estimated impacts and in fact over time tend to average out to an impact similar to that predicted for the modeled array.

The basic acoustic terminology used in this appendix is presented in numerous published sources (e.g., ANSI, 1986, 1984; Richardson et al., 1995; NRC, 2003; Southall et al., 2007). The main definitions used in this assessment are provided below (Southall et al., 2007):

- *Pulses*: Pulses are brief, broadband, atonal, transient sounds; e.g., explosions, gun shots, airgun pulses, and pile driving strikes. Pulses are characterized by a rapid rise from ambient pressure to maximal pressure, and (at least near the source) by short duration.
- *Nonpulse (intermittent or continuous) sounds*: Nonpulse sounds can be tonal, broadband, or both. Nonpulse sounds can be of short duration but they lack the rapid rise times of true pulses. Nonpulse sounds include those from shipping, aircraft, drilling, and active sonar systems. Due to certain propagation effects, it is possible that a sound that is pulsed near the source may be perceived by a distant receiver as a nonpulse sound.
- *Peak sound pressure*: This is the maximum instantaneous sound pressure measurable in the water at a specified distance from the source airgun. The units of pressure are

typically bars (English) or, in metric units, either Pascals (Pa) or micropascals (μPa). The metric values are commonly expressed in logarithmic form as decibels relative to 1 μPa (dB re 1 μPa).

- *Peak-to-peak sound pressure*: This is the algebraic difference between the peak positive and peak negative sound pressures. Units are the same as for peak pressure. When expressed in dB, peak-to-peak pressure is typically ~ 6 dB higher than peak pressure.
- *Root mean square (RMS) sound pressure*: In simple terms, this is an average sound pressure over some specified time interval. For airgun pulses, the averaging time is commonly taken to be the approximate duration of one pulse, which in turn is commonly assumed to be the time interval within which 90% of the pulse energy arrives. The RMS sound pressure level (in dB) is typically ~ 10 dB less than the peak level, and ~ 16 dB less than the peak-to-peak level.
- *Sound pressure levels (SPLs)*: SPLs are given as the dB measures of the pressure metrics defined above. The RMS SPL is dB re: 1 μPa for underwater sound and dB re: 20 μPa for aerial sound.
- *Source Level (SL)*: SL is the received level measured or estimated at a nominal distance of 1 m from the source. It is often expressed as dB re: 1 μPa at 1 m or in bar-m. For a distributed source, such as an array of airguns, the nominal overall source level, as used in predicting received levels at long distances, exceeds the level measurable at any one point in the water near the sources.
- *Sound exposure level (SEL or energy flux density)*: This measure represents the total energy contained within a pulse, and is in the units dB re 1 $\mu\text{Pa}^2\text{-s}$. For a single airgun pulse, the numerical value of the SEL measurement, in these units, is usually 5–15 dB lower than the RMS sound pressure in dB re 1 μPa , with the “RMS – SEL” difference often tending to decrease with increasing range (Greene, 1997; McCauley et al., 1998).
- *Duration*: Duration is the length of the sound, usually measured in seconds. For an impulsive sound such as an airgun pulse, the duration may be calculated in a number of different ways. Greene (1997) described duration of an airgun pulse as the interval over which 90% of the sound energy arrives at the receiver.

Over the past decade, NMFS guidelines regarding levels of impulsive sound that might cause disturbance or injury have often been based on the “RMS sound pressure” metric. However, the RMS value depends on the extent to which the sound pulse has been “stretched” in duration during propagation, which varies with environmental conditions, so the RMS measure is often criticized (e.g., Madsen, 2005). There is now reason to believe that auditory effects (especially physiological effects like PTS and TTS) of transient sounds on marine mammals are better correlated with the amount of received energy than with the level of the strongest pulse and therefore SEL is increasingly the unit of choice in evaluations.

1.2 ACOUSTIC MODELING APPROACH

There are two steps to the modeling effort: 1) the determination of the 3-D acoustic field emanating from the sound sources and how it propagates through the water; and 2) the determination of the net exposure of marine animals that reside in the exposed volume.

Historically, the seismic community and NMFS have used a simplified approach to estimate the potential impacts to marine mammals for airgun sources. In this document, this methodology is called the line-transect calculation methodology. Essentially, this methodology consisted of: 1) determination of the estimated threshold isopleth range from the source (nominally these thresholds were the 160 dB received level for Level B and 180 dB received level for Level A (cetaceans) harassment under the Marine Mammal Protection Act (MMPA)) (see Table A-1) for the airgun sources; 2) assumption that a cylinder whose radius matched the range to these isopleths and encompassed the entire water column, was ensonified to that threshold; 3) calculating the surface area ensonified by this water column as the source moved along its track; and 4) multiplying that resultant ensonified surface area by the density of each marine mammal species present to estimate that species numbers of MMPA Level A and B potential harassment takes. This methodology will be included in this document for comparison and continuity.

Additionally, a more sophisticated approach will be included in this document. This approach will use a more detailed modeling of the source and its properties, the acoustic propagation field in three dimensions, and three dimensional animal placement and movement to better calculate the potential impacts to marine mammals. For this methodology, the first step is largely controlled by properties of the source, such as its movement in time and space, and the sound field it generates at any point in time. This is a function of the geometric organization (array configuration) of its sound generators, and the spatial, spectral and temporal properties of the sound field that they produce. Propagation modeling further analyzes the effects of the physical properties of the ocean, the bottom and the surface on the sound field as it propagates out from the source.

The second step requires knowledge of the diving and movement characteristics of the animals residing in the exposed region. Time-based integration models, such as the Acoustic Integration Model[®] (AIM)¹, as used in this modeling effort, are necessary to fully evaluate the exposure. The advantage of these tools is that they not only provide a more accurate and detailed model of the exposures of a population of marine animals in the three dimensions and time, but they also provide: 1) statistical data on each individually modeled animal and the population as a whole; 2) rate of exposure (sounds per unit time) over the duration of a survey; and 3) the data necessary to determine effects based on more sophisticated thresholds, such as sound exposure level, SEL.

1.2.1 Propagation Modeling

1.2.1.1 Overall Modeling Assumptions

For the more complex modeling effort detailed in this appendix the following general assumptions were made:

¹ MAI's Acoustic Integration Model[®], or AIM, is a software package developed to predict the acoustic exposure of marine animals from an underwater sound source. The unique and principal component of AIM is a 3-D movement engine, which programs the geographic and vertical movements of sound sources and simulated marine animals. In 2006, the Center for Independent Experts (CIE) conducted a review and assessment of AIM. The CIE panel concluded that AIM is a credible tool for developing application models (Independent System for Peer Review 2006).

- The far-field broadband signal from the typical airgun array nominally includes significant components up to 1,000 Hz, with the peak amplitude in the far-field near-horizontal spectrum typically occurring between 50 and 100 Hz;
- The modeling needed to address all of the acoustic survey types are identified in Chapters 1 and 2;
- A nominal or representative source, as identified by BOEMRE and industry, will be used for source modeling and source specification identification;
- Conditions to be modeled need to include all potential survey areas in the northern Gulf of Mexico, including three water depths: shallow, slope, and deep water, and all four seasons;
- Animal density estimates would use the best available data, which would need to be specified by location and season for the modeling effort; and
- Animal movement modeling would use the best available input data.

1.2.1.2 Acoustic Propagation Model Selection

Three acoustic propagation models were readily available and generally considered capable of meeting the modeling objectives, allowing for the limitations of the models as derived from Dozier and Cavanagh (1993) and OAML (2002). These models are: a) a U.S. Navy-approved version of the Parabolic Equation (PE) Model; b) the Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS/GRAB) Model; and c) the Bellhop Model. Although all three acoustic models potentially can be used for this modeling effort, each has water depth and frequency limitations. After a review of the capabilities and limitations of each model, the CASS/GRAB model was selected for this analysis because: a) it is capable of modeling propagation between 50 Hz and 1,000 Hz; b) its built-in array beamformer code has been found to be adequate for modeling the array patterns throughout the analysis frequency range; c) it is readily compatible with the supporting databases that would be used; d) it allows a selection of the range and depth steps (i.e., the resolution of the modeled propagation field) that is necessary; and e) it allows an examination of the spreading of the seismic signal as caused by the acoustic multi-path throughout the propagation field.

CASS/GRAB is a U.S. Navy standard acoustic propagation model that is applicable for frequencies between 150 Hz and 100 kHz (OAML, 2002). The U.S. Navy sponsor for the CASS/GRAB model states that, although it had been tested and provided good predictions at frequencies down to 50 Hz, the lower limit has not been approved nor implemented in the U.S. Navy's Oceanographic and Atmospheric Master Library (OAML) (2002) database. CASS/GRAB does have a nominal [depth > $2 \times \pi \times \text{wavelength}$] limitation, so for depths less than approximately 100 m for a 100 Hz signal, care must be exercised when using this model.

1.2.1.3 Overview of Essential Supporting Databases

- **Surface Loss Model**—Surface Loss Models are available and function well down to a frequency of 1 Hz. The specific model used for this modeling effort was the U.S. Navy standard OAML (2002) surface reflection coefficient model. This model is directly available internal to the CASS/GRAB model.
- **Bathymetry**—This modeling effort will use Digital Bathymetry Data Base–Variable resolution (DBDB-V) (0.1-2.0 nautical miles resolution) (OAML 2002).
- **Bottom Loss**—Bottom loss characterization for specific sites must be determined individually, with the task becoming more complex with lower frequencies. The specific model used for this modeling effort was the Rayleigh bottom reflection coefficient model. This model is directly available internal to the CASS/GRAB model.
- **Sound Velocity Profile (SVP)**—The SVPs used in this modeling effort were derived from the monthly-averaged Generalized Digital Environmental Model (GDEM) database.

1.2.1.4 AIM Modeling and Comparative Assessment of Exposure

The Acoustic Integration Model[®] (AIM) is a four-dimensional, individual-based, Monte Carlo statistical model designed to predict the exposure of receivers to any 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. AIM uses external range-dependent stimulus propagation models (e.g., CASS/GRAB for this modeling effort) and additional propagation models can be integrated to accommodate any class of propagation stimuli, including acoustic and explosive.

1.2.2 Overall Modeling Approach

The following step-wise modeling approach is included to illustrate the overall approach to predict the acoustic impacts of seismic (airgun) sources in the Gulf of Mexico for the proposed action:

- The GDEM database of SVPs was used to extract SVP for the GOMEX and to characterize the water body into four SVP regions;
- SVP for winter, spring, summer and fall were then examined for these regions (note after examination of the SVPs it was determined that the summer and winter propagation patterns captured the extremes of the possible propagation fields and that the spring and fall were transitions between these extremes. In shallow water, both seasons were effectively iso-velocity, which resulted in minimal differences in transmission loss, thus only winter profiles and modeling were used there. But for the deep and intermediate (slope) cases, both the summer and winter profiles were subsequently modeled.);
- DBDB-V was used to determine where the four SVP regions overlap with the three depth sub-regions, characterized as shallow, slope, and deep;

- Consider the SVP regions with the three depth sub-regions, and determine if any of the resulting acoustic propagation situations are duplicative and can be eliminated to reduce the number of acoustic model runs required;
- The spectrum of the airguns below 1,000 Hz was divided into the American National Standards Institute (ANSI) standard 1/3rd octave bands;
- CASS/GRAB was utilized to construct the 3-D beam patterns for the source for each of these 1/3rd octave bands. Embedded in this modeling for each of 1/3rd octave bands are the specific source levels and beam patterns for that 1/3rd octave. It should be noted that these beam patterns were compared to a 3-D beam pattern produced by an industry model (GUNDALF) and the difference was minimal.
- CASS/GRAB was run for each of the 1/3rd octave bands, for a total of 5 separate propagation situations and 2 seasons, as identified above. Each of these propagation runs included a 15° resolution in azimuth to fully characterize propagation for that site. As expected, the 50 to 100 Hz bin typically showed less TL on a per-Hz basis than was evident for higher frequencies, but occasionally some slight near-surface ducting was observed at the higher frequencies (i.e., 600-1,000 Hz);
- In order to capture the broadband nature of the transmission loss for the seismic signal a technique was developed which integrates the 1/3rd octave transmission loss fields for the specific seismic signal and spectrum identified as the nominal case. The resulting TL estimate provides a reasonable but conservative estimate of the received level footprint for the airgun source, which reflects contributions to the result from the entire source spectrum, for each 15° azimuth for each site; and
- AIM is used to estimate the impacts per survey block, based on the transect line geometry for each type of survey in each modeled site, for each of the thresholds used in the modeling.

1.3 ACOUSTIC THRESHOLDS

1.3.1 Historical Criteria.

Since the mid-1990s, the National Marine Fisheries Service (NMFS) has specified that marine mammals exposed to pulsed sounds with received levels exceeding 180 or 190 dB re 1 μ Pa (RMS) for cetaceans and pinnipeds, respectively, were considered to exceed Level A (Injury) levels (NMFS, 2000). Similarly, NMFS also considers that cetaceans and pinnipeds exposed to levels \geq 160 dB re 1 μ Pa (RMS) were considered to exceed Level B (Behavioral) levels (Table A-1). For all of these criteria, the exposure level was the maximum acoustic RMS pressure level received by an animal.

Table A-1. Historical Injury and Behavior Criteria for Cetaceans and Pinnipeds, as Recognized and Used by the U.S. National Marine Fisheries Service

Group	Level A (Injury) Pressure (dB re 1 μPa RMS)	Level B (Behavior) Pressure (dB re 1 μPa RMS)
Cetaceans	180	160
Pinnipeds	190	160

1.3.1.1 Injury Criteria.

The 180- and 190-dB re 1 μ Pa (RMS) criteria were determined before there was specific information about the received levels of underwater sound that would cause temporary or permanent hearing damage in marine mammals. Subsequently, data on received levels that cause the onset of temporary threshold shift (TTS) have been obtained for certain toothed whales and pinnipeds (Kastak et al., 1999, 2005; Finneran et al., 2002, 2005). A group of specialists in marine mammal acoustics, the “noise criteria group”, has recommended new criteria, based on current scientific knowledge, to replace the somewhat arbitrary 180 and 190 dB (RMS) criteria (Southall et al., 2007).

Recently acquired data indicate that TTS-onset in marine mammals is more closely correlated with the received energy levels than with RMS levels. In odontocetes and the more sensitive pinnipeds exposed to nonpulse sound, TTS onset occurs near 195 and 183 dB re 1 μ Pa²-s, respectively (Southall et al. 2007). In odontocetes exposed to impulse sounds, the TTS threshold can be as low as approximately 183 dB re 1 μ Pa²-s. The corresponding value for pinnipeds is less well defined. There are published data on levels of nonpulse sound (Kastak et al., 1999, 2005) but not of impulse sound eliciting TTS in pinnipeds. Based on the results for nonpulse sound, plus the known tendency in other mammals for lower TTS thresholds with impulse than with nonpulse sound, the TTS thresholds for pinnipeds exposed to impulse sound may be as low as 171 dB re 1 μ Pa²-s in the more sensitive species, such as the harbor seal.

There are no specific data concerning the levels of underwater sound necessary to cause permanent hearing damage (permanent threshold shift or PTS) in any species of marine mammal. However, data from terrestrial mammals provide a basis for estimating the difference between the (unmeasured) PTS thresholds and the measured TTS thresholds. A conservative (precautionary) estimate of this offset between TTS and PTS thresholds, when sound exposure is measured on a sound exposure level (SEL) basis (received energy levels), is to add 15 dB to the TTS value for impulsive sounds and 20 dB for nonpulse sounds (Southall et al. 2007). Thus, now-available data indicate that the lowest received levels of impulsive sounds (e.g., airgun pulses) that might elicit slight auditory injury (PTS) are 198 dB re 1 $\mu\text{Pa}^2\text{-s}$ in cetaceans (i.e., 183 + 15 dB), and 186 dB re 1 $\mu\text{Pa}^2\text{-s}$ in the more sensitive pinnipeds (i.e., 171 + 15 dB). Corresponding values for nonpulse sounds (e.g., marine vibrator sweeps) are 215 re 1 $\mu\text{Pa}^2\text{-s}$ in cetaceans (i.e., 195 + 20 dB) and 203 dB re 1 $\mu\text{Pa}^2\text{-s}$ in the more sensitive pinnipeds (e.g., 183 + 20 dB) (Southall et al., 2007). These SEL measures are all assumed to be taken using M-weighting; i.e., somewhat down-weighting the energy for frequencies near and especially beyond the lower and upper frequency limits of hearing in the relevant marine mammal group (Southall et al. 2007).

The noise criteria group 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 (Table A-2).

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. The most appropriate interval over which the received airgun signal should be accumulated is not well defined. However, pending the availability of additional relevant information, the noise criteria group has suggested considering noise exposure over 24-hr periods.

Table A-2. Injury and Behavior Exposure Criteria for Cetaceans and Pinnipeds, as proposed by Southall et al., (2007)

<i>Group</i>	Level A (Injury)		Level B (Behavior)
	Pressure	Energy	Pressure
	(dB re 1 μPa RMS)	(dB re 1 $\mu\text{Pa}^2\text{-s}$)	(dB re 1 μPa RMS)
Low Freq. Cetaceans	230	198	*
Mid. Freq. Cetaceans	230	198	*
High Freq. Cetaceans	230	198	*
Pinnipeds (in water)	218	186	*

Sources: NMFS, 2005; Southall et al., 2007. Note: * means not specified in Southall et al., 2007

1.3.1.2 Behaviour Criteria

As noted above, the existing U.S. NMFS criterion for potential disturbance to marine mammals from airgun-based seismic surveys is 160 dB re 1 μ Pa (RMS). The noise criteria group concluded that available data are insufficient as a basis for recommending any specific alternative disturbance criteria applicable to multiple-pulse sounds like airgun array sounds (Southall et al., 2007). Other methodologies, including the possible use of a risk continuum function as was used in the SURTASS LFA Sonar FEIS and FSEIS (DoN, 2001a and DoN, 2007a) are being examined for Level B impact assessment for various sources at this time, but none has been applied to the impact analysis for this PEIS.

Acoustic impact criteria applicable to other types of biota are less well developed than are the criteria for cetaceans and pinnipeds. There is an ongoing effort to develop science-based criteria for fish and sea turtles.

2.0 DETAILS OF THE ACOUSTIC IMPACT MODELING

2.1 SOURCE DESCRIPTION AND MODELING

2.1.1 Acoustic Source Levels

As stated previously in Section 1.2 of this appendix, the source levels (peak-to-peak, zero-to-peak, and RMS) and the far-field broadband signal spectrum used for this modeling effort were provided by industry and consist of measured values for the identified “nominal” airgun array modeled throughout this analysis. Since the majority of the threshold criteria use an RMS received pressure level to estimate potential impact to marine mammals, the source will be modeled as a point source with the appropriate beam pattern (for each one-third octave band) and RMS pressure source level.

The exception to this approach is necessitated by the SEL threshold criteria identified in Section 1.3 of this appendix, which uses an integrated energy received level, or sound exposure level (SEL). Typically, the SEL of a signal can be conservatively estimated by the equation:

$$\text{SEL in dB re } 1 \mu\text{Pa}^2\text{-s} \approx \text{SL(RMS)} + 10\text{LOG}_{10}(\text{T}_{\text{DUR}})$$

Where:

SL(RMS) = the RMS SL of the pulse in dB re 1 μ Pa @ 1 m.

T_{DUR} = the duration of the dominant pulse.

The difficulty here is in selecting an appropriate value for the duration of the signal, because the spreading of the signal is a function of: a) the source depth; b) the range and depth from the source; and c) the propagation conditions for the modeled site. There is not a simple or easily identified rule or equation which can readily provide the value of the effective spreading of the signal as it propagates out from the source, especially for the various water depth and

propagation modes necessary to represent the entire Gulf of Mexico. However, detailed and accurate calculations of the signal spread is a natural by-product of the acoustic propagation modeling, because the CASS/GRAB model used in this analysis calculates the arrival structure of the numerous acoustic multi-paths that the signal uses for each range and depth step of the overall solution. As part of the acoustic propagation modeling effort described later in this appendix, the signal spread or signal duration was examined for the three depth regions of the Gulf of Mexico, for six different frequencies modeled at each site, for four depth slices in the propagation field out to at least 30 km. The result of this examination was for any multi-path arrival whose received level was within 20 dB of the maximum arrival value for that depth and range from the source, no signal duration exceeded 0.1 s. And most of the signal durations were one or more orders of magnitude below 0.1 s (i.e., they were 0.01 s or less in duration). Therefore, a conservative value of 0.1 s is used for the signal duration for this analysis, with a resulting SEL value of 220 dB re 1 $\mu\text{Pa}^2\text{-s}$ at one meter from the modeled point source ($\text{SEL} = 230 + 10 \text{ LOG}_{10} [0.1] = 220 - 10 = 220 \text{ dB re } 1 \mu\text{Pa}^2\text{-s at } 1 \text{ m}$).

2.1.2 Beamforming

Modeling the physical acoustics of airgun operations can be complicated. There are specifically designed and dedicated programs that predict the output characteristics of single airguns and airgun arrays. GUNDALF is one such program. GUNDALF takes into account airgun interactions including non-linearities and interactions between sub-arrays: “No assumptions of linear superposition are made and the engine is capable of modeling airgun clusters down to the 'super-foam' region where the bubbles themselves collide and distort. GUNDALF has been calibrated against both single and clustered guns for a number of different gun types under laboratory conditions and accurately predicts peak to peak and primary to bubble parameters across a very wide range of operating conditions” (Hatton, 2008).

CASS/GRAB is a U.S. Navy standard model that can be run internally and whose performance has been well documented (Weinberg, 2001). While CASS/GRAB does not model bubble interactions, it can (unlike GUNDALF), model the propagation of acoustic energy out to long distances through a complex marine and sub-bottom environment, a necessary part of this study. However, we must first determine how well the CASS/GRAB array beam generator model captures the important features of airgun array operation. To do so we compared GUNDALF results for an airgun array used in this PEIS (Figure A-1) with CASS/GRAB beamforming and propagation runs for the same array parameters. It is important to recognize that although

GUNDALF and CASS/GRAB may perform similar functions/calculations, but they may follow a different order of computation. Most relevant here is that the beam pattern generator of GUNDALF takes into account air/water surface interactions. The CASS/GRAB beam pattern generator model does not; it assumes a free field when calculating the beam pattern. Surface interactions and other environmental factors are taken into account by CASS/GRAB during the propagation modeling step.

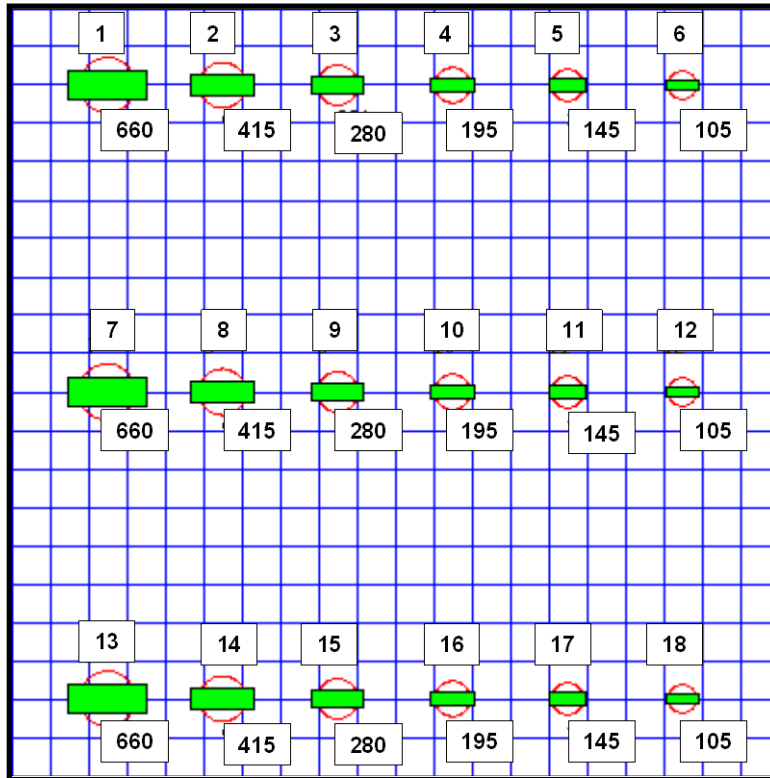


Figure A-1. Airgun Array Used for GUNDALF Modeling and CASS/GRAB Comparison. Values Listed are Airgun Number (above) and Volume in Cubic Inches (below).

The first comparison is between the inline directivity (along the tow axis of the array) and the crossline directivity (perpendicular to the tow axis), as modeled by GUNDALF and by the CASS volumetric array beam pattern model. Figures A-2 and A-4 show the inline and crossline beam patterns, respectively, produced by GUNDALF. In Figure A-2 and A-4, horizontal lines (black and gray) are the frequencies used for comparison with CASS/GRAB model results. The gray arrowhead points out a null, or ghost, at 125 Hz and the white arrowheads point out the peak side beams for the source at 125 Hz. Figures A-3 and A-5 show the inline and crossline beam patterns from the CASS/GRAB array beam pattern model. The beam patterns in these two figures are shown as attenuation in dB, as it is produced and used in CASS/GRAB. The overall beam pattern is well accounted for by the beam pattern-generator model of CASS. Note, however, that the ‘ghosting’ effects due to interaction with the air/water surface are not accounted for here. They are included later in the modeling process of the CASS/GRAB model. The important issue is the agreement of the overall beam pattern.

There is very good agreement between beam patterns generated by GUNDALF and by the CASS array beam pattern generator. However, an obvious feature that is missing from the CASS beam pattern is destructive interference, or ‘ghost’ lines, that result from acoustic interaction with the air/water surface. As pointed out above, the CASS beam pattern model does not take into account surface interactions at this stage, whereas they are included in GUNDALF.

In order to verify that the CASS/GRAB model does eventually and accurately include the effects of the surface “ghosting,” it is necessary to examine the propagation “field plot” (i.e., modelled transmission loss field, as a function of range and depth) in the immediate vicinity of the array as modelled by CASS/GRAB. Note that with CASS/GRAB the three dimensional volumetric airgun array has been modelled as a point source with a beam pattern, and it is this beam pattern, which includes ocean surface reflections, which will be seen in these field plots. For simplicity here, examples will be given at the lower frequencies where the beam patterns are the simplest (i.e., the fewest side-lobes and generally the widest beams), but comparisons were made for all frequencies up to 1,000 Hz and all bearings (i.e., -90 to +90 degrees) and the CASS/GRAB model demonstrated very good agreement with that produced by the GUNDALF model.

At 75 Hz, the CASS/GRAB field plots for inline and crossline directions are show in Figures a-6 and A-7. As expected when compared to the gray lines at 75 Hz in Figures A-2 and A-4, the main beam points directly downward and it is about 100 degrees wide (50 degrees to each side of vertical) and there is no ghost null. Also, there are no real side lobes or side beams at this frequency. Note also that all of the field plots presented here do not have equal range and depth scales, so care must be taken when measuring angles in these figures. As the frequency increases in Figures A-2 and A-4, the main beam width continues to decrease, until at about 125 Hz the ghosting null nearly completely eliminates the main beam at a directly downward direction. Figures A-8 and A-9 show the inline and crossline field plots for the CASS/GRAB model at 125 Hz. Note the that the downward beam is greatly reduced and actually less than the side beams, which occur at about 60 and 50 degrees, respectively for the inline and crossline cases. As the frequency continues to increase to 175 Hz, Figures A-10 and A-11, the CASS/GRAB main beam has grown again to a width of about 70 or 50 degrees for the inline and crossline cases, respectively, and a strong ghost null is present at about 45 degrees and a small side lobe at about 70 to 80 degrees.

For completeness, examples of CASS/GRAB field plots are also provided for 300 Hz (Figures A-12 and A-13) and 1,000 Hz (Figures A-14 and A-15).

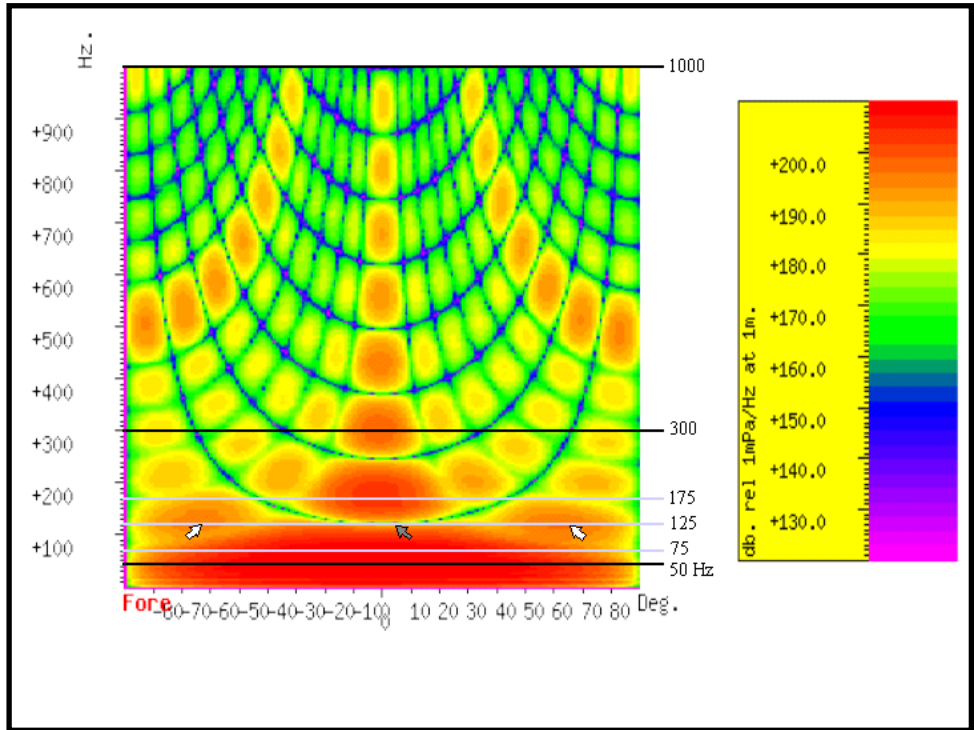


Figure A-2. GUNDALF Array Beam Pattern - Inline Direction (i.e., along the tow axis of the array).

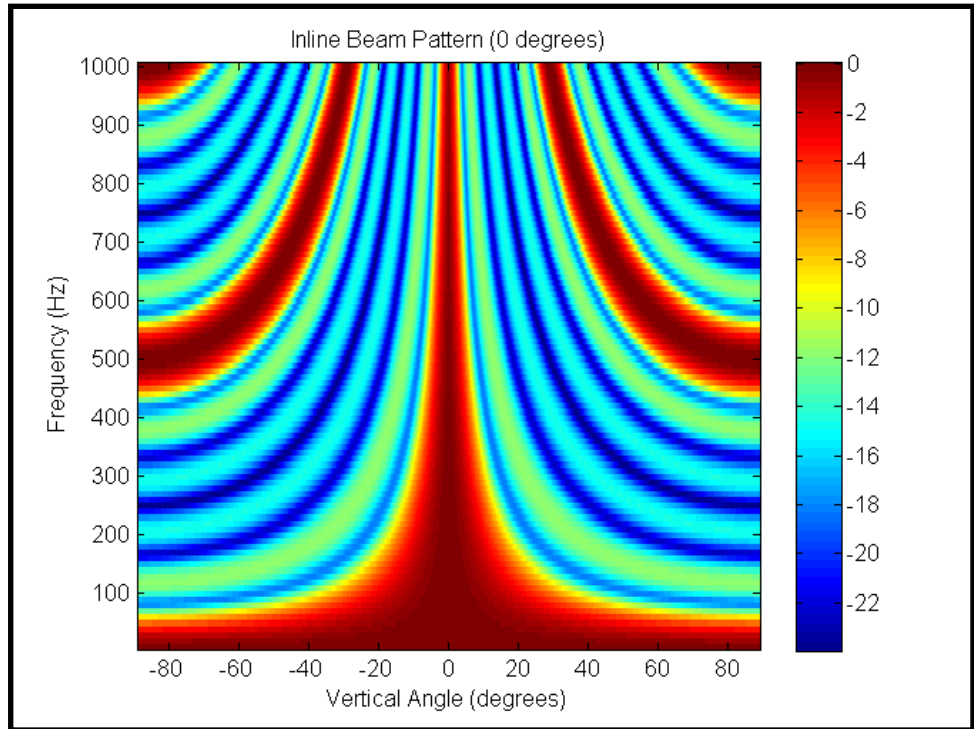


Figure A-3. CASS/GRAB Array Beam Pattern – Inline Direction.

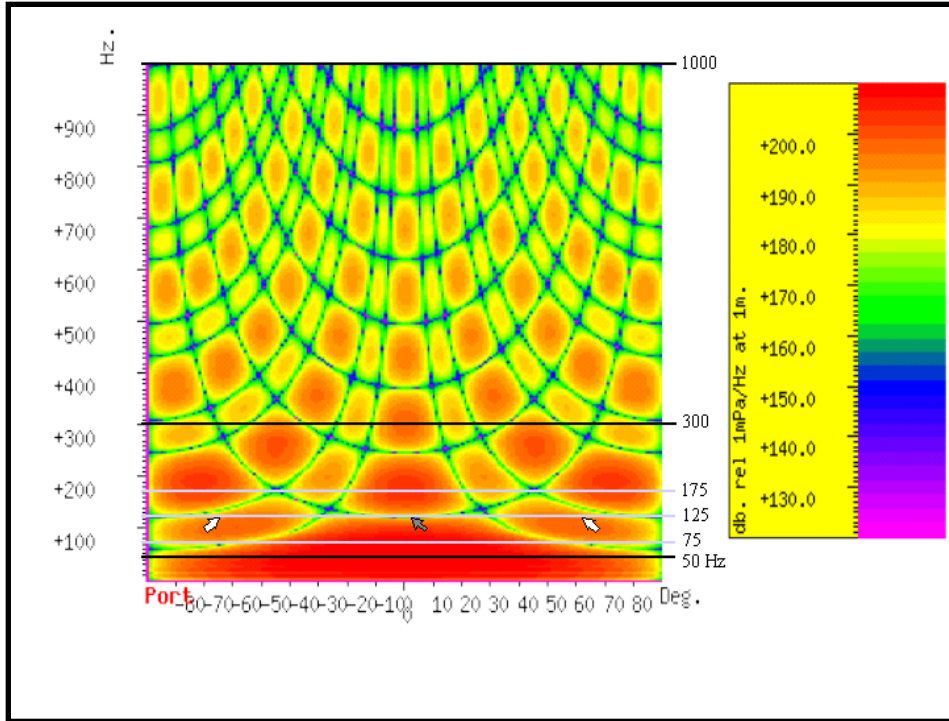


Figure A-4. GUNDALF Array Beam Pattern - Crossline Direction (i.e., perpendicular to the tow direction).

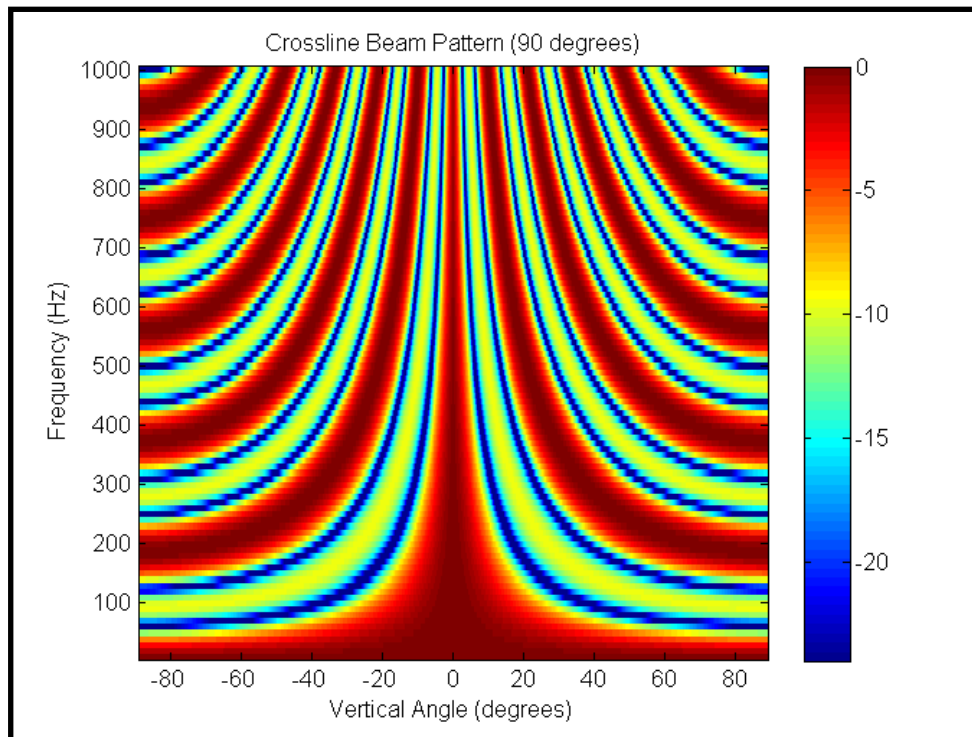


Figure A-5. CASS/GRAB Array Beam Pattern – Crossline direction.

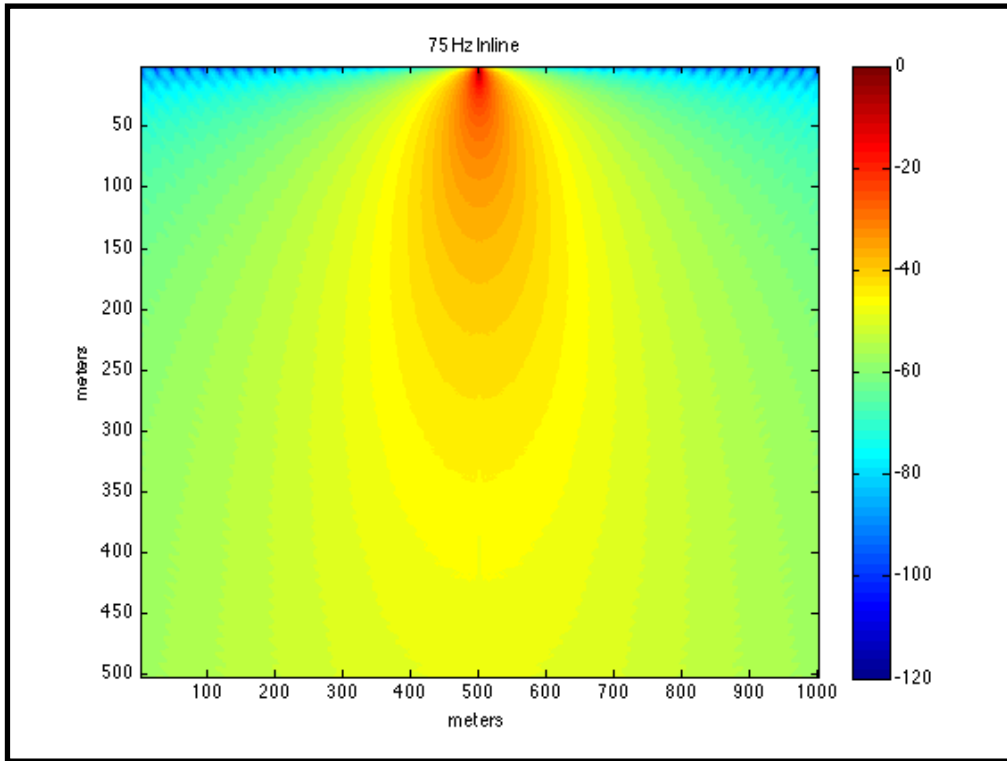


Figure A-6. CASS/GRAB Inline Field Plot for 75 Hz.

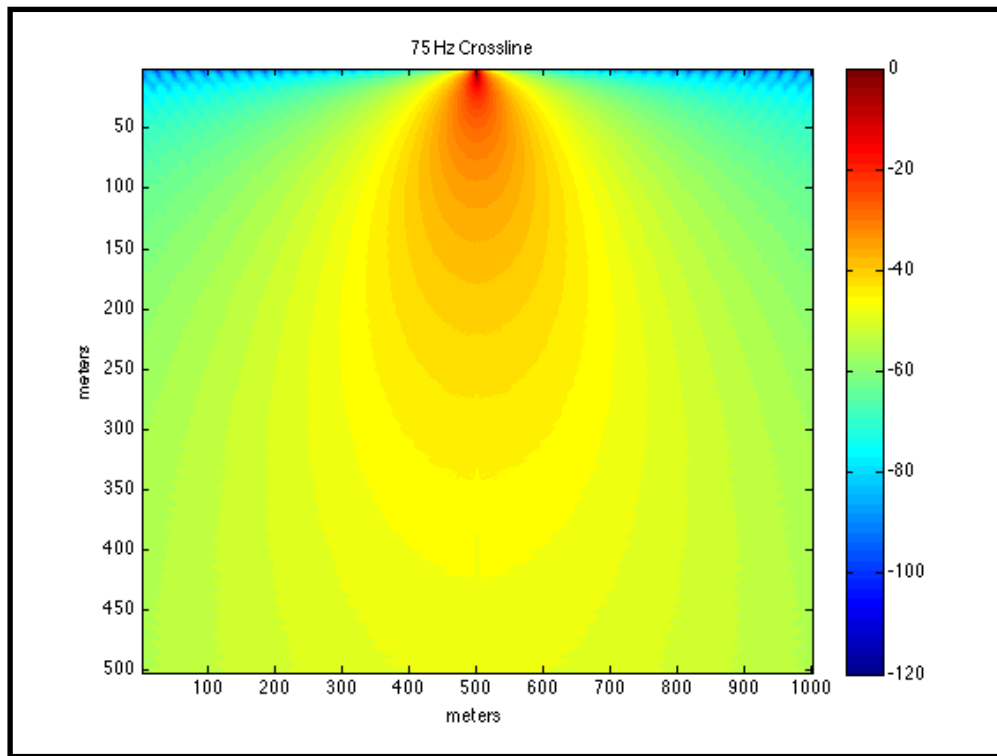


Figure A-7. CASS/GRAB Crossline Field Plot for 75 Hz.

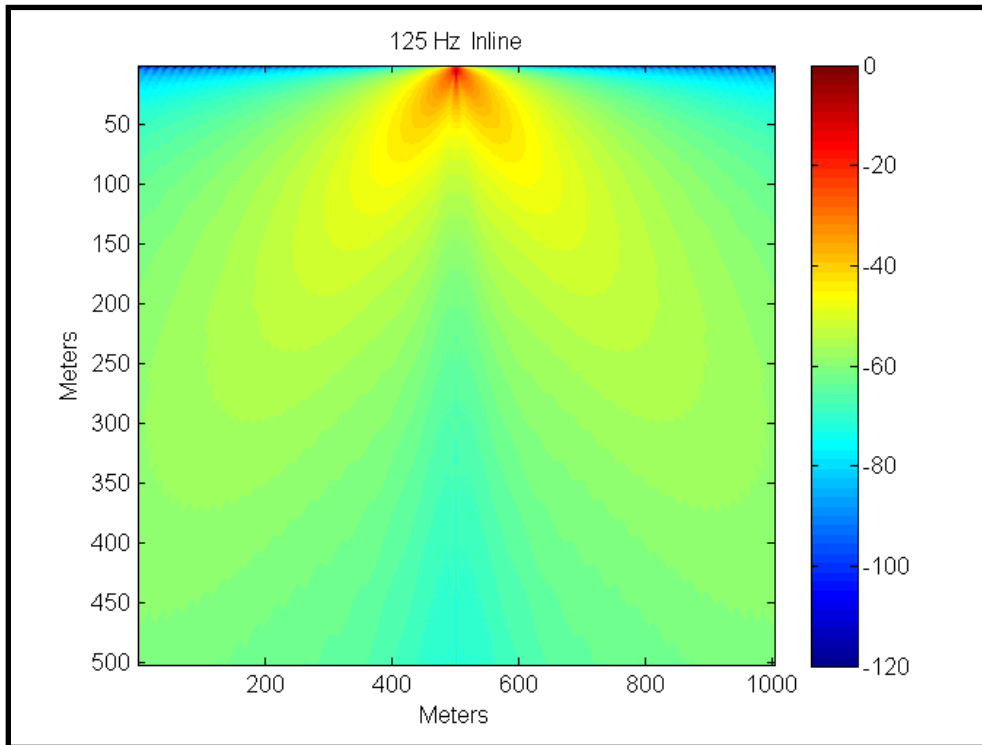


Figure A-8. CASS/GRAB Inline Field Plot for 125 Hz.

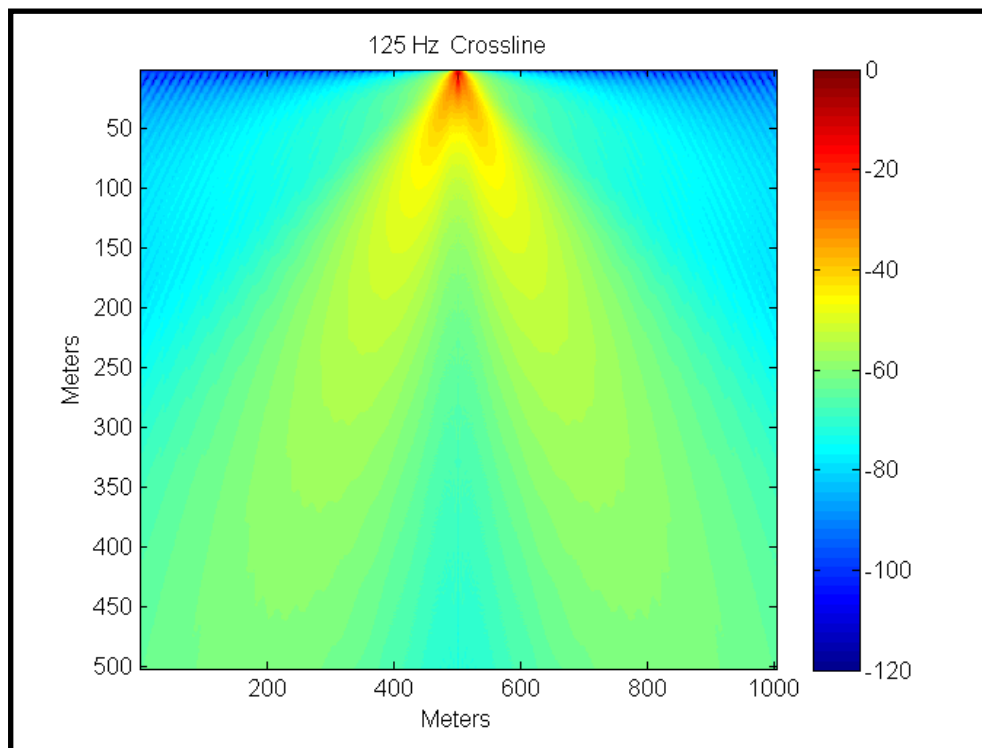


Figure A-9. CASS/GRAB Crossline Field Plot for 125 Hz.

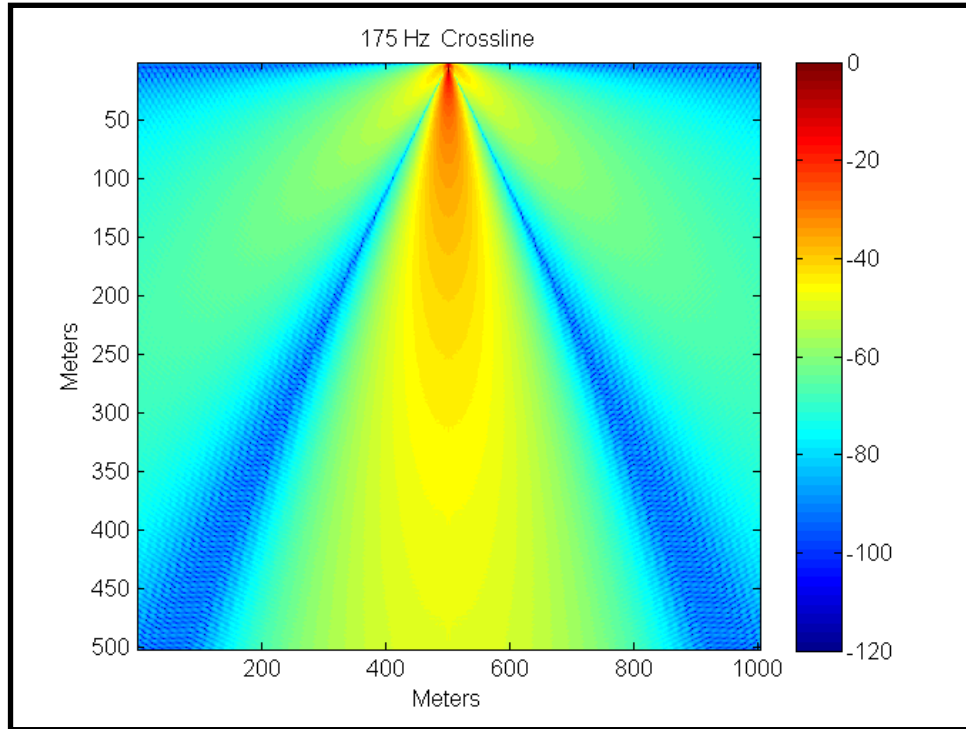


Figure A-10. CASS/GRAB Inline Field Plot for 175 Hz.

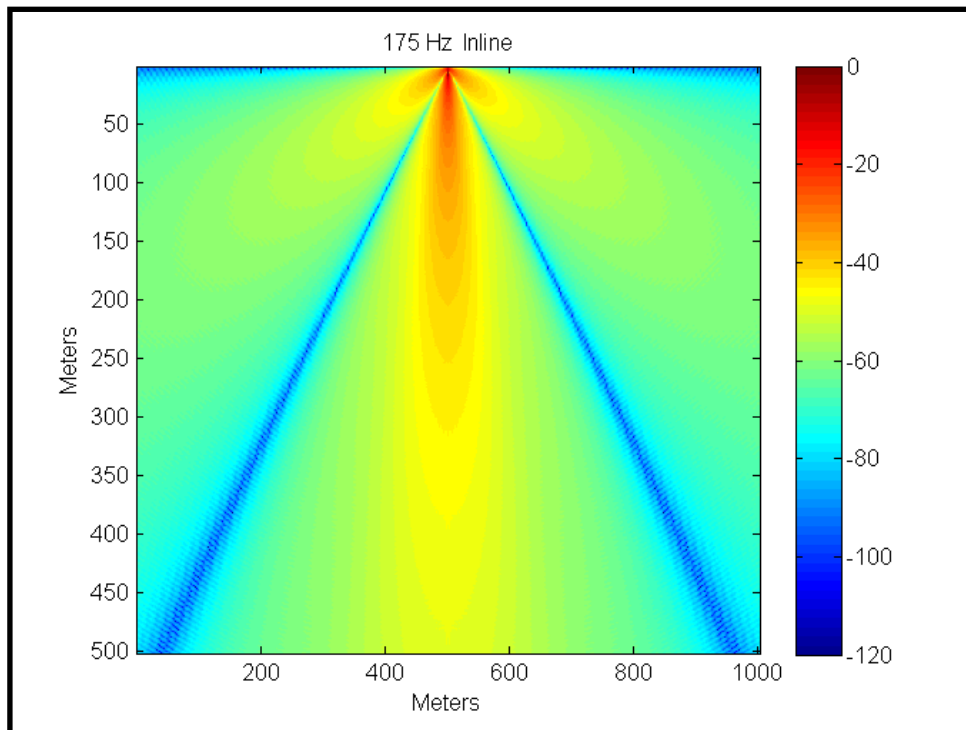


Figure A-11. CASS/GRAB Crossline Field Plot for 175 Hz.

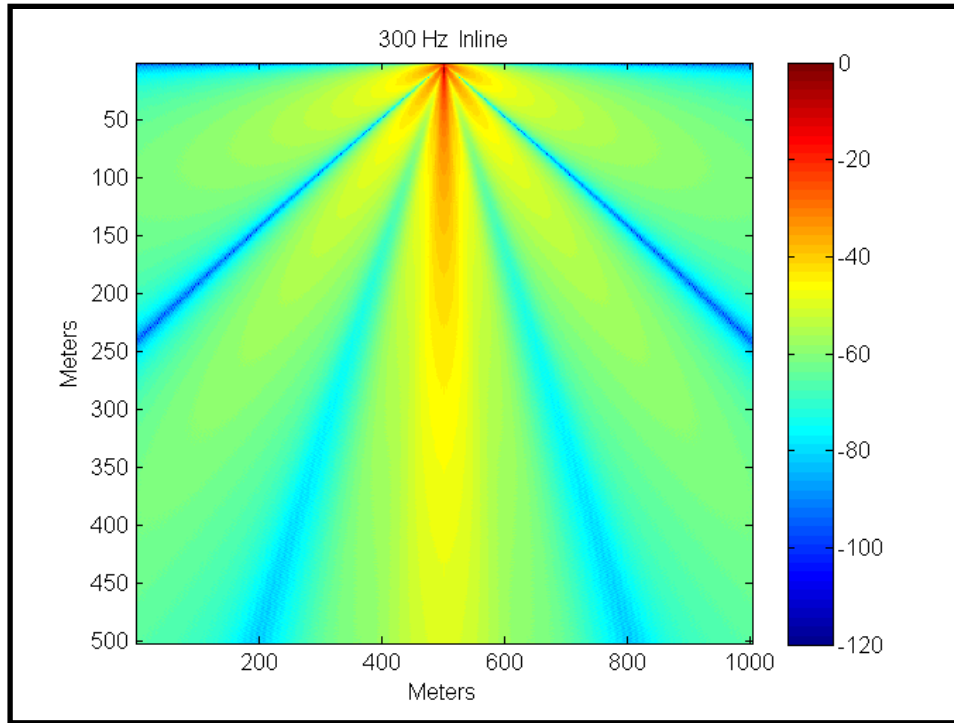


Figure A-12. CASS/GRAB Inline Field Plot for 300 Hz.

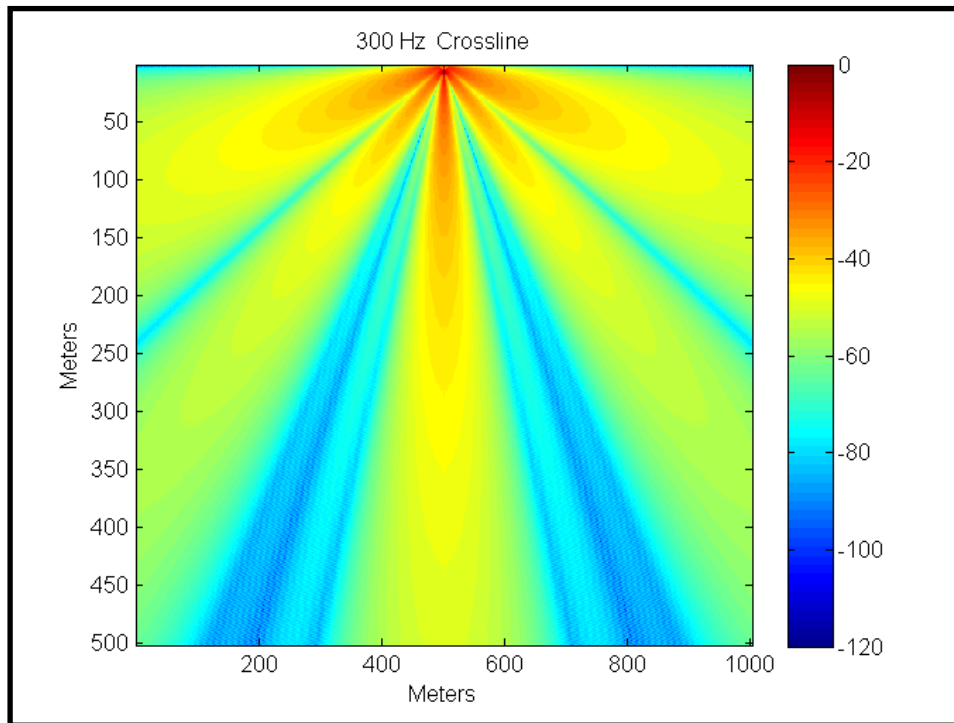


Figure A-13. CASS/GRAB Crossline Field Plot for 300 Hz.

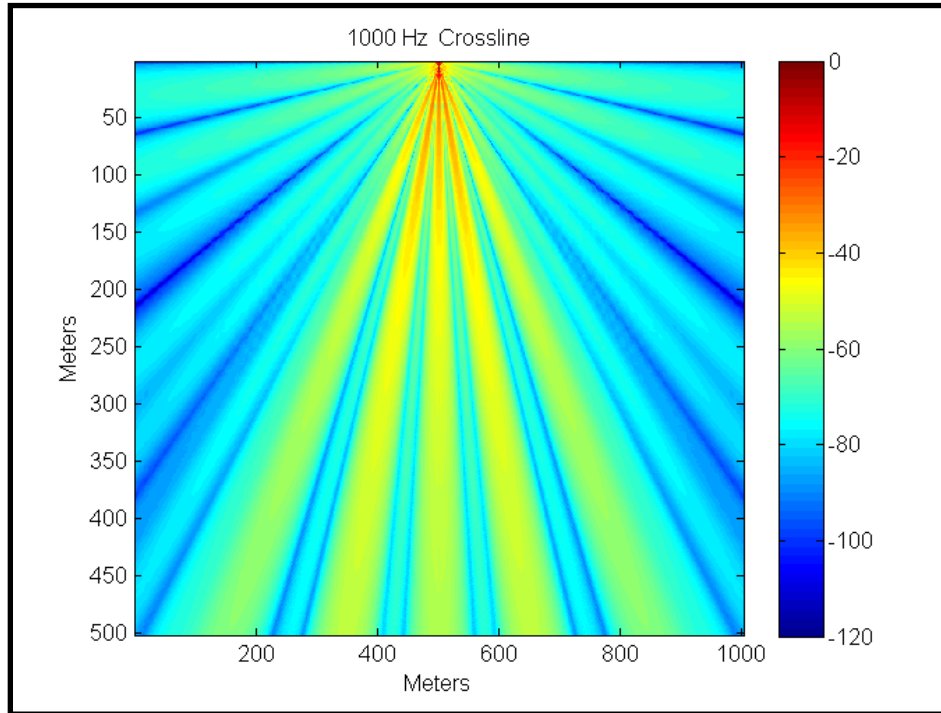


Figure A-14. CASS/GRAB Inline Field Plot for 1,000 Hz.

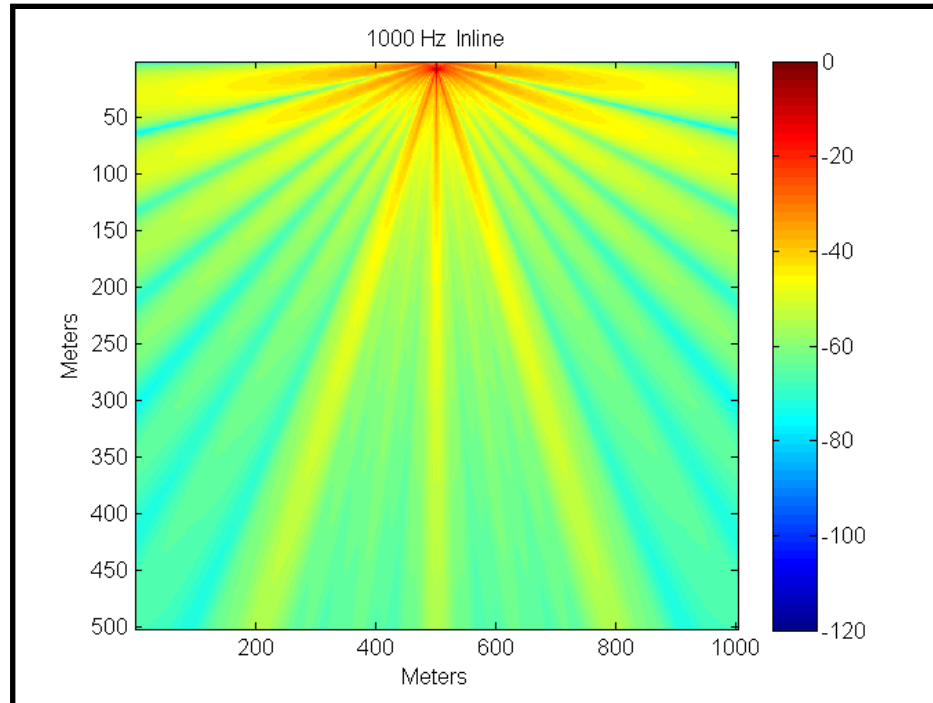


Figure A-15. CASS/GRAB Crossline Field Plot for 1,000 Hz.

2.2 SURVEY OPERATIONS

Details of the various survey types and how they were modelled are provided in Section 2.6 of this appendix.

2.3 M-WEIGHTING

Southall et al. (2007) formally introduced the concept of M-weighting, which is designed to account for the different hearing sensitivities of different groups of marine mammals. The basic M-weighting functions are shown in Figure A-16. For all analyses in this document, M-weighting will only be applied to MMPA Level A impact calculations, and then only when specifically identified.

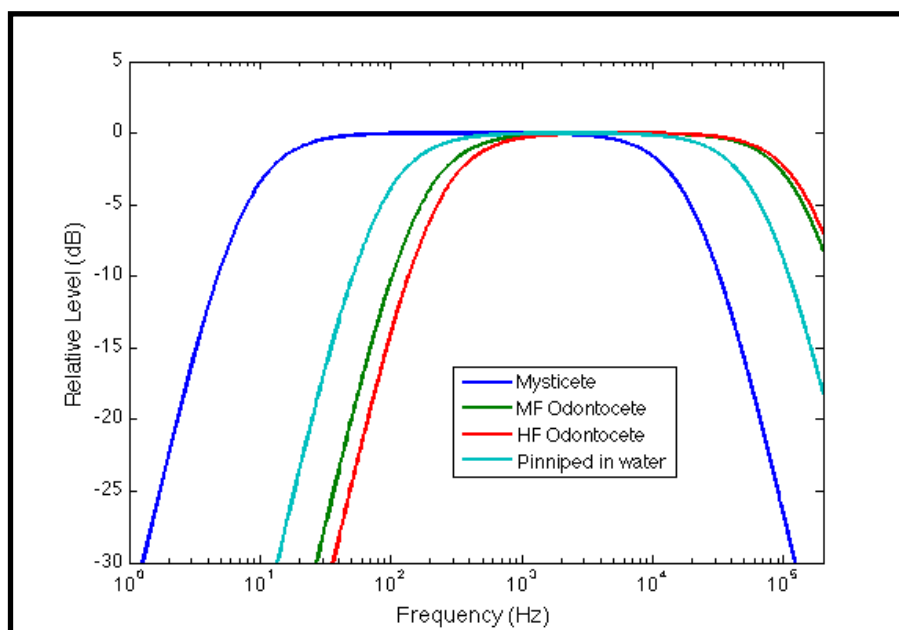


Figure A-16. M-weighting Functions for In-water Marine Mammal Species.

The goal of this section is to explain the conversion of these spectral presentations into a scalar that represents the effect of M-weighting upon a broadband source. Figure A-17 shows the spectrum of an airgun signal as simulated by the GUNDALF model (Hatton, 2008) as a black line. The spectrum was then weighted by summing the spectrum of the airgun with the M-weighting functions for the mysticete and mid-frequency (MF) odontocetes categories. The difference between the M-weighted and flat curves was then determined and shown as the red and blue curves, respectively.

Subsequently, the amplitudes were converted from decibels to pressure values for each curve, and the pressures for frequencies between 10 and 1,000 Hz were then summed. Frequencies below 10 Hz were excluded as a conservative application of the M-weighting functions. The

ratio of the sums of the M-weighted and un-weighted pressures were then converted back to decibels. These scalar values represent the net difference in the received level at the animal due to the effects of M-weighting and are presented in Table A-3.

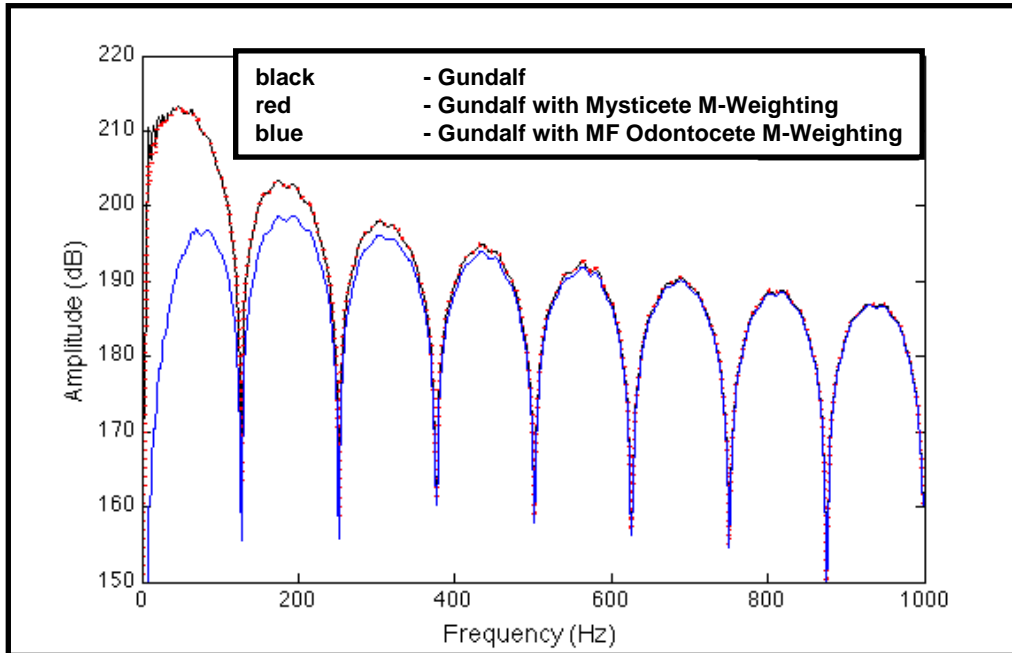


Figure A-17. Effect of M-weighting on Airgun Frequency Spectrum.

This procedure accounts not only for the effect of the M-weighting, but the spectral characteristics of the original signal itself. The scalar values in Table A-3 should be applicable to most, if not all, airgun signals, but not other broadband signals. This procedure can be repeated for other broadband signals with other spectral characteristics.

Table A-3. Scalar Offset values for M-weighting.

M-weighting Class	dB offset
low-frequency cetaceans	-0.3
mid-frequency cetaceans	-10.4
high-frequency cetaceans	-12.2
pinnipeds in water	-6.5

2.4 ENVIRONMENTAL MODELING

2.4.1 INTRODUCTION

As previously mentioned in Section 1.2, the acoustic modeling effort involved two main steps: (1) physical acoustic modeling to predict the three dimensional (3-D) underwater sound field around airgun sources; and (2) use of a second model to determine and correctly interpret the exposure of marine animals exposed to that sound field. The Acoustic Integration Model (AIM) will be used to complete the second step and that will be discussed further in Section 2.6 below. This section will describe the environmental modeling methodology used to characterize the sound field around the airgun sources.

The overall approach to the environmental modelling effort is to use the best available propagation models and databases to characterize the underwater sound propagation for the Gulf of Mexico (i.e., those portions of the northern Gulf of Mexico regulated and leased by BOEM and potentially those regulated by the various states too) for potentially, year-round source operations. Due to the nature of the airgun sources, the frequency range of interest was identified to be between 50 and 1,000 Hz. Although airguns can and do produce acoustic energy above 1,000 Hz, the reduced source levels at these frequencies (i.e., typically 20 to 30 dB less than the maximums at frequencies between 50 and 200 Hz (see Figure A-2) or measured at more than 70 dB less than the maximum values (note that the difference between these two spectrums is that for the former the values are modelled at the source, and for the latter they are measured at 9,000 meters after propagation loss, where higher attenuation selectively reduces the higher frequency portion of the spectrum), along with the increased attenuation of acoustic signals as frequency increases, ensure that using 1,000 Hz modelling adequately and conservatively represents this higher frequency portion of the spectrum. Because of the requirement to ensure that the frequency-dependent beamforming and source spectrum levels of the sources is appropriately accounted for in the modelling, an eigenray propagation model was selected for ease of examining numerous intermediate stages of the results in the modelling effort.

2.4.2 POTENTIAL ISSUES WITH MODELING METHODOLOGIES

Three potential issues arise due to the identified need to model shallow water in the Gulf of Mexico. The first issue is that the combination of the shallow water depth and the lowest frequencies to be modeled (i.e., 25 to 50 Hz) ensure that the acoustic propagation model (CASS/GRAB) is operating at the edge (or even slightly beyond the edge) of the “2 Pi lambda” limitation of the physics upon which the model is based (i.e., two times Pi times the wavelength of the frequency being modeled). Beyond this limitation, the accuracy and reliability of the model’s results degrades in unpredictable ways (i.e., minor changes in a seemingly innocuous parameter may cause a rapid change in the results). During the modeling effort, extra care was taken to examine the shallow water modeling results for these frequencies to determine if any unpredicted behavior occurred in these results. The combined facts that: a) no unusual results were observed, and b) these low frequencies were not the dominant contributors to the spectrum of the received acoustic energy, indicates that any error arising for this reason should not be considered significant.

The second issue also results as a combination of the water depth and frequency of the transmitted signal. The eigenray model, as it was used here, assumes that the source is a sufficient distance from any boundaries (i.e., the surface and the ocean bottom) so that a far-field beam pattern can be superimposed on the calculated eigenrays as corrections to the source level. These corrections are a function of azimuthal bearing and angular difference from the main lobe or the vertical reference. In actuality, for the lowest frequencies examined, the beam pattern probably does not completely form in the shallow water case before the acoustic energy interacts with the bottom. This complication is reduced somewhat by the fact that the main source of acoustic energy propagating out from the source comes from the angles nearer to the horizontal plane and not the more vertical rays, which do interact with the bottom frequently and rapidly attenuate. The near-horizontal rays generally have a greater distance to travel before bottom interactions. As will be shown later in this section, the generally iso-velocity character of the sound velocity profiles for the modeled shallow water area, will allow these near-horizontal rays to propagate with limited surface and bottom interaction, or at very low grazing angles (i.e., low levels of reflection loss) and thus be the driving factor for received acoustic energy at ranges beyond approximately the first kilometer.

The third and final issue is the degree of accuracy with which the bottom parameters are known and modeled, especially for the lower frequencies, which are much more capable of penetrating the sediment. As will be discussed below, this modeling effort generally used a “representative” value for the range of parameters available or possible in the modeled areas, but also tended to err on the conservative side by using those parameters which resulted in a lesser value of transmission loss (i.e., a higher received level at the modeled animals). Therefore, the possible detrimental effects of this issue are minimized in the modeling parameters selected. Finally, it should be noted that for a “representative” study like this one, the results should not be compared to measured data of any type, especially for a specific situation, without exercising extreme care.

2.4.3 MODELING PARAMETER AND DATABASE SELECTIONS

The following discussion specifies the acoustic propagation model, input databases and other support data used to model and characterize the year-round propagation expected to be present in the Gulf of Mexico. All models and databases needed to be capable of handling the entire spectrum of conditions potentially present in the Gulf of Mexico (i.e., those portions of the northern Gulf of Mexico regulated and leased by BOEM), from the very shallow near-coastal waters out to the deep waters of the Gulf. Additionally, this section will identify the methodology used to select a limited number of representative sites, which are then used to adequately characterize the acoustic propagation of airgun sources throughout the specific area.

2.4.3.1 Acoustic Propagation Model

The acoustic propagation model is the U.S. Navy standard Comprehensive Acoustic Simulation System (CASS) Model version 4.0 and the Gaussian Ray Bundle (GRAB) version 2.0. CASS provides the interface to the various environmental, system and propagation models available and already embedded in it, while GRAB (the default eigenray calculation model) was the actual eigenray calculation engine used for these calculations. CASS/GRAB is a range-dependant

model that is capable of incorporating the specific beam patterns produced by the airgun array (for the full range of specific frequencies selected) and the historic environmental parameters for the ocean sound velocity profile, bathymetry, ocean surface conditions and the characteristics of the ocean bottom. Officially, GRAB can accurately model active-source range-dependent propagation and reverberation for frequencies from 150 Hz to 100 kHz (OAML, 2002). However, additional testing of the model down to 50 Hz has been conducted satisfactorily and it is believed that eventually the official frequency range for this model will be expanded to recognize this fact.

2.4.3.2 Sound Velocity Profiles

The ocean database used to supply the sound velocity profiles (SVPs) used in this study is the U.S. Navy standard Generalized Digital Environmental Model Variable Resolution (GDEM-V) database, version 3.0. GDEM-V provides a global-gridded monthly mean (and standard deviation) of ocean salinity and temperature. For the region being studied here, this database provides resolution of 15-arc minutes in both latitude and longitude. A plot of the GDEM-V province numbers for the Gulf of Mexico (Figure A-18) shows a total of 5 provinces, identified as 159, 166, 176, 183 and 181, in the portion of the Gulf of Mexico covered by this document (i.e., the area north of the thick black line in Figure A-18). Two of these provinces only occur for a very small area (i.e., <1% of the area of the Gulf of Mexico being studied) and only adjacent to the area's boundaries in the extreme southeastern portion of the study area (i.e., roughly in the vicinity of the Florida Keys and the Dry Tortugas Islands). For simplicity, these two GDEM-V profiles, 181 and 183, will not be analyzed further. The remaining three profiles, 159, 166, and 176 will be used for all subsequent acoustic propagation modeling. A plot of the average monthly values for each of these three provinces (Figures A-19, A-20 and A-21) shows the monthly changes to the profiles throughout the year.

For each of the three provinces, representative SVPs were selected for each of the four seasons and the resulting modeled propagation predictions were examined. It was determined that, as expected, the summer and winter propagation conditions were the extremes of the environment, and in all cases sound propagated better during the winter. In shallow water, both seasons were effectively iso-velocity, which resulted in minimal differences in transmission loss, thus only winter profiles and modeling were used there. But for the deep and intermediate (slope) cases, both the summer and winter profiles were subsequently modeled.)

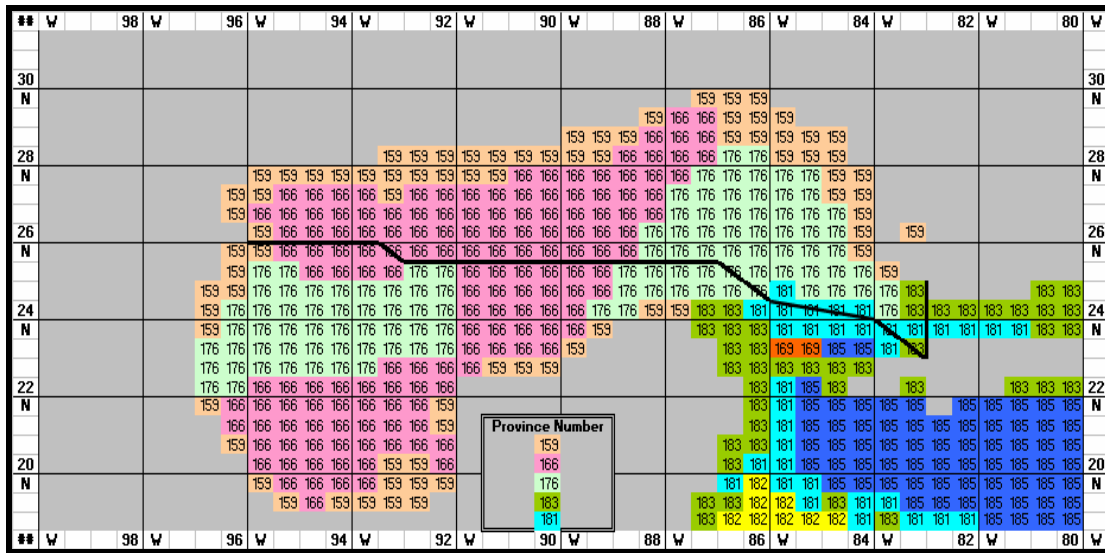


Figure A-18. GDEM Province Numbers Plotted for the Gulf of Mexico.

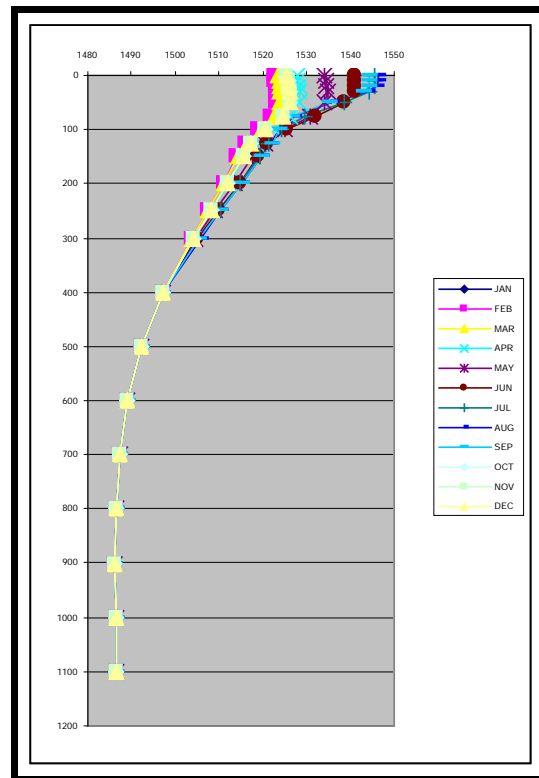


Figure A-19. Average Monthly SVPs for Province 159.

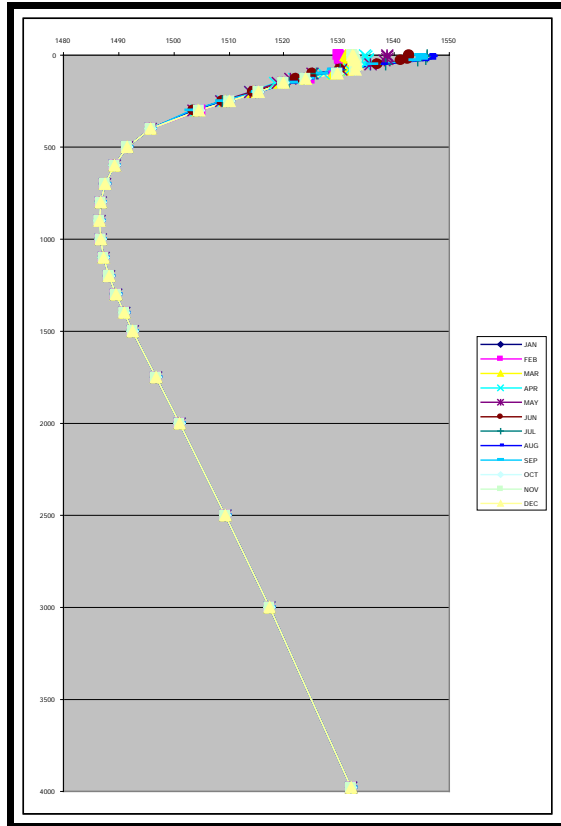


Figure A-20. Average Monthly SVPs for Province 166.

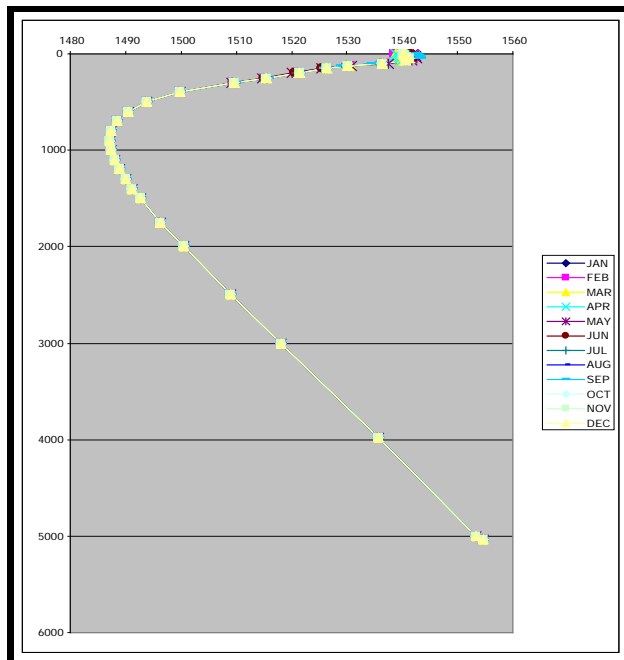


Figure A-21. Average Monthly SVPs for Province 176.

Actual airgun operations during spring, summer, and fall months would likely involve less-efficient sound propagation and therefore reduced potential environmental impact.

2.4.3.3 Bottom Topography/Bathymetry

The bathymetric database used for all modeling in this report is the U.S. Navy standard Ocean Floor Depth Digital Bathymetric Database Variable Resolution (DBDB-V), version 4.3 (level 0) (OAML, 2002). This is an unclassified version of the database that provides 0.05 arc-min data resolution in the modeled area for both latitude and longitude.

2.4.3.4 Bottom Loss

The CASS/GRAB acoustic model was used to predict transmission loss at each site. Integral to the CASS/GRAB model is the Rayleigh bottom loss model, which predicts the amount of acoustic energy loss as the eigenray is reflected off the bottom. The Rayleigh bottom loss model predicts the amount of loss as a function of incident angle of the acoustic propagation path to the bottom and the frequency being modeled. The Rayleigh bottom loss model assumes that a simple harmonic plane-wave is reflected from an interface between two fluids that have different sound speeds and densities. The characteristics of the bottom sediment determine the values of different sound speeds and densities. Bottom sediment characteristics were determined by using the NOAA National Coastal Data Development Center (NCDDC) Coastal Ecosystems Program database for the Gulf of Mexico (NOAA-NCDDC, 2009). The Gulf of Mexico sediment database depicts shelf sediment textures, hard banks, and gravel deposits on the continental shelf of the U. S. Gulf of Mexico as a map and is summarized from numerous different sources (DoN, 2007c). The sediment database was prepared from existing sources to accompany an Environmental Impact Statement, and displays general classification of bottom sediments (using the Shepard pyramid) throughout the Gulf of Mexico. It was provided by the U.S. Department of the Interior, Minerals Management Service, and Gulf of Mexico OCS Regional Office. Inputs to the Rayleigh bottom loss model sound speed differences and sediment density were inferred using the Applied Physics Laboratory-University of Washington (APL-UW) method and grain size determined from the NCDDC database.

2.4.4 Combining SVP, Bathymetry, and Bottom Sediment Data to Identify Modeling Areas

Next, the geographic distribution of the preceding three sets of data (i.e., SVP, bathymetry and bottom sediment type) were examined to identify regions of similar characteristics in order to simplify and reduce the acoustic propagation (and subsequently AIM) modeling effort, but yet adequately represent the conditions present in the Gulf of Mexico. Additionally, since marine animal distribution and density for each species also vary throughout the Gulf of Mexico, consideration of animal geographic distribution preferences were also taken into account. Section 2.5 of this appendix describes the data used to model the specific animal density for any location in the Gulf of Mexico, but in general the marine mammals can be roughly identified as shelf (i.e.,

shallow water), slope, or deep water species, for any given season. This characterization does not preclude a species presence in other water depths during that season, but it does indicate where that population may be concentrated and the range over which it is distributed.

When the SVP, bottom sediment type, bathymetry and Shelf Planning Areas were overlaid, it was determined that there was a natural and reasonable division of the Gulf of Mexico into nine regions, each of which had a nearly universal value for its various acoustic modeling parameters. For example, all three shallow (shelf) regions have the SVP profile # 159 as their predominant profile Table A-4 list the nine regions and the acoustic parameter species descriptor associated with it.

Table A-4. Regions of the Gulf of Mexico and Pertinent Parameters.

#	Acoustic Parameters			Geographic Parameters	Biological Parameters
	Water Depth	SVP Profile	Sediment Type	Shelf Planning Area	Species Type
1	shallow	159	sand (2.5)	Eastern	shelf
2	shallow	159	sand (2.5)	Central	shelf
3	shallow	159	sand (2.5)	Western	shelf
4	slope	159	sand (1.5)	Eastern	slope
5	slope	159	sand (1.5)	Central	slope
6	slope	159	sand (1.5)	Western	slope
7	deep	176	clay (9.0)	Eastern	deep
8	deep	166	clay (9.0)	Central	deep
9	deep	166	clay (9.0)	Western	deep

Note: 1) Water depth definitions: shallow 0-200 m, slope 200-1,000 m, deep >1,000 m.
 2) Number in parentheses after the sediment type is the grain size.

Essentially, these nine regions can be further consolidated into four representative acoustic propagation modeling sites by:

- combining the three shallow sites into one site,
- combining the three slope sites into one site, and
- combining sites 8 and 9 into one site.

This was done and since a specific site, with azimuthally-dependent bathymetry, is necessary for the acoustic propagation modeling by the CASS/GRAB model, representative sites with specific latitude and longitude coordinates were selected for each of the four acoustically modeled sites (Table A-5, Figure A-22).

Table A-5. Acoustic Modeling Regions of the Gulf of Mexico and Representative Sites.

Model Site #	Region #	Acoustic Parameters			Geographic Location	
		Water Depth	SVP Profile	Sediment Type	Latitude	Longitude
1	1, 2, 3	shallow	159	sand (2.5)	28° 15.0' N	094° 00.0' W
2	4, 5, 6	slope	159	sand (1.5)	27° 50.0' N	092° 30.0' W
3	7	deep	176	clay (9.0)	27° 15.0' N	093° 30.0' W
4	8, 9	deep	166	clay (9.0)	28° 00.0' N	086° 30.0' W

2.4.4.1 Wave Height or Surface Wind

With the identification of the parameters associated with the four acoustic modeling sites above and their associated environmental acoustic parameters (i.e., specific bathymetry, SVPs and bottom sediments that are associated with each site), the only environmental parameter that still need to be identified before acoustic modeling can occur is the surface wave height or the representative surface wind speeds for each site. Data from NOAA's National Data Buoy Center (NDBC) were retrieved for buoy Number 42019, which is located off Freeport, Texas at 27° 54' 47"N, 95° 21' 36"W (NOAA-NDBC, 2008). This NDBC buoy is on the continental shelf, near the shelf edge and far enough offshore to be exposed to winds similar to those that would be observed near modeled sites # 1, 2, and 3. Thus it was used to model the wind conditions for all locations. These buoy data show a strong seasonal pattern of higher wind speeds and wave heights during the winter and reduced wind speeds and wave heights during the summer (Figures A-23 and A-24; NOAA-NDBC, 2008). During the winter average wind speed can be as high as 15 knots (kts), while in summer the average wind speed is about 8 kts. Similarly, the mean peak wind speeds approaching 20 kts in winter and dipping to near 10 kts in summer. The extremes of the wind speed distributions follow the same pattern, with the lowest values observed in July.

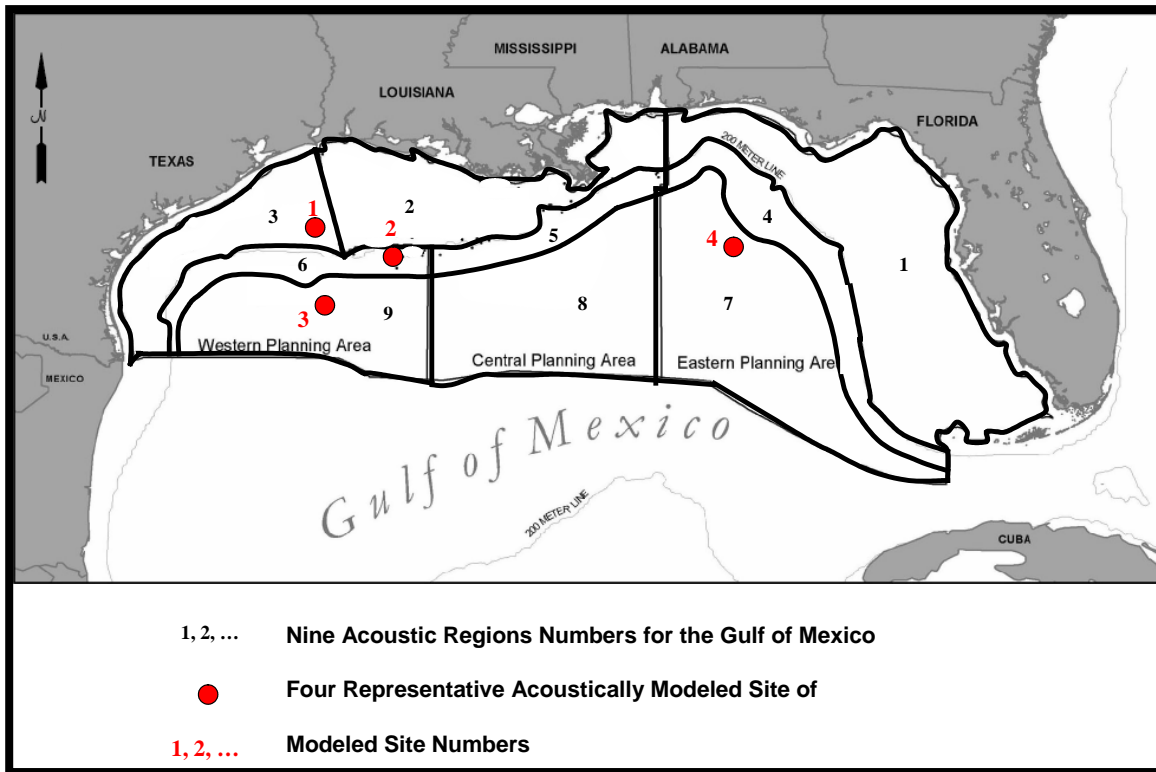


Figure A-22. Acoustic Regions and Representative Model Sites in the Gulf of Mexico.

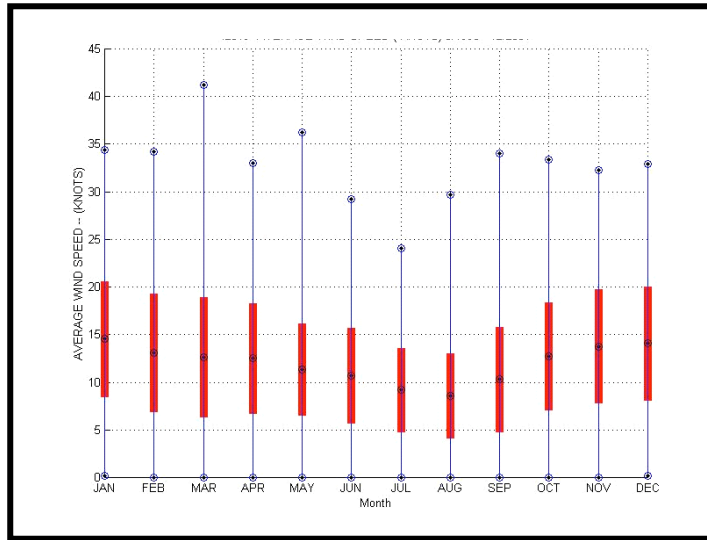


Figure A-23. Average Wind Speed Data Collected Near the Modeling Sites (NOAA-NDBC, 2008).

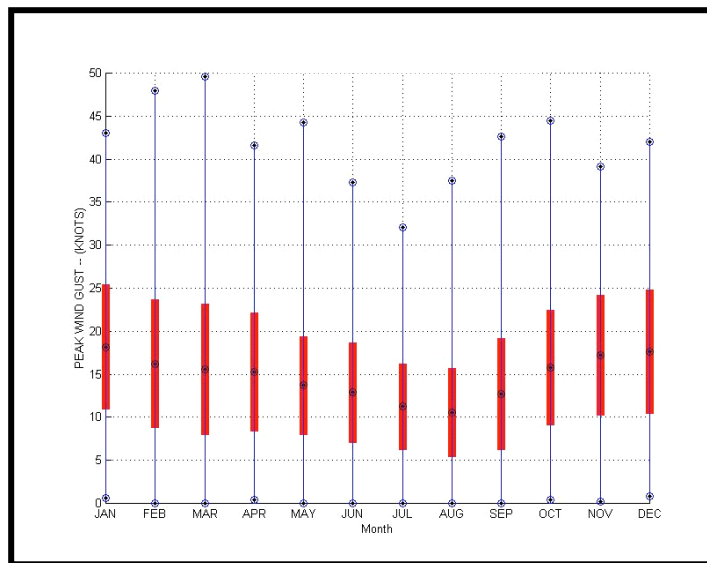


Figure A-24. Peak Wind Speed Data Collected Near the Modeling Sites (NOAA-NDBC, 2008).

Wave height data were also collected at the NDBC buoy (NOAA-NDBC, 2008). A plot of the wave height data (Figure A-25) shows the same strong seasonal pattern as the wind speed data, with mean wave heights approaching 1.5 m in winter and dipping to below 1 m in summer. These seasonal wave height data were applied conservatively (i.e., producing the least TL) for the acoustic propagation modeling.

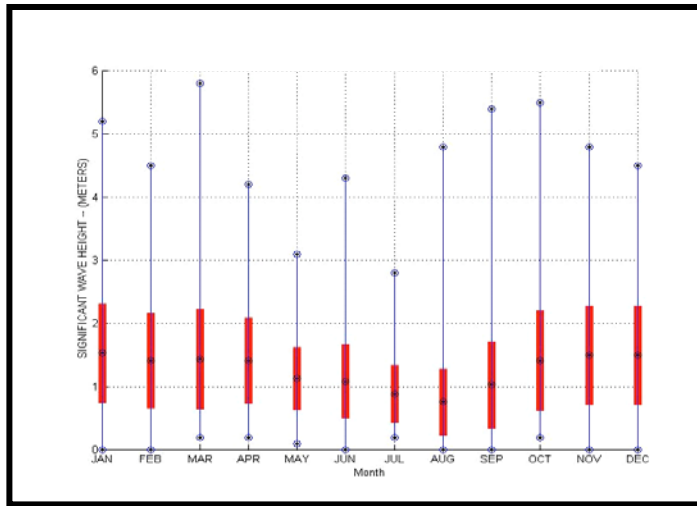


Figure A-25. Average Wave Height Data Collected Near the Modeling Sites (NOAA-NDBC, 2008).

2.4.4.2 Model Receiver Parameters

For this modeling analysis, all receivers are modeled as perfect omni-directional receivers. This is a conservative assumption, given that the marine animals that were simulated during the AIM portion of the modeling probably have some directivity for any frequency of sound that they can perceive, and better directivity as the frequency of the signal increases (§8.4 in Richardson et al., 1995). Additionally, the CASS/GRAB model has been programmed to coherently add all eigenrays in its pressure calculations. Therefore, during the calculation of the peak pressure and total energy arriving at the receiver, essentially, all eigenrays are added in a method that includes accounting for their phase.

2.4.5 ACOUSTIC MODELING

2.4.5.1 Model-Specified Parameters and Resolution

Prior to executing the final transmission loss acoustic modeling run, which would be used in the impact calculations, several preliminary modeling run sessions were completed to allow examination of the range of TL results and to assist in specifying the internal model parameters, such as maximum range, range and depth increments (or resolution), azimuthal resolution, etc.

It was during these preliminary model runs that the seasonal effects on the SVPs and subsequently, the TL, were examined, as described in the “Sound Velocity Profile” topic of section 2.4 above. The resulting conclusion to use the winter profiles was shown in this modeling

effort to be the most appropriate methodology as it yields nominal yet moderately conservative results (i.e., the least transmission loss, or greatest received levels occurred when the winter profiles were used) for all of the model sites and SVPs.

The second parameter examined was the azimuthal resolution of the TL runs for each site. Here, the primary variability of the model runs was highly dependent on the range-dependency of the bathymetry as the model extended outward from the source location along each bearing. This translates into different received levels (RLs) for a modeled position in the water (or a modeled animal at the position) depending on the bearing from the source. It was determined that this resolution was especially important for the shelf and slope sites, where bathymetry can vary greatly based on the azimuth chosen, but less so for the deep-water situation. A bearing resolution of 15° was found to be adequate for the shelf and slope sites, while a resolution for deep water was 90° or more. For consistency, an azimuthal bearing resolution of 15° was universally adapted for all sites.

A maximum range for the modeling of 30 km (16.2 nmi) was identified as necessary to capture all possible RL of 140 dB re 1 µPa RMS, or higher for the modeled source. This is certainly adequate for the primary acoustic threshold used in this document for Level B impacts (i.e., 160 dB re 1 µPa RMS) and it covers most of the potential range of RLs for potential future threshold approaches (e.g., use of a risk continuum). Therefore, it was adopted as the maximum range for the acoustic modeling used in this document.

Throughout the acoustic modeling, a 50 m (164 ft) range increment and a 5 m (16.4 ft) depth increment were used to resolve the sound field. This resolution extended out to the maximum range of 30 km (16.2 nmi), and the maximum depth (i.e., the ocean bottom) anywhere within 30 km of each site.

The acoustic spectrum produced by the modeled airguns includes frequencies up to 5 or 10 kHz and beyond. However, an examination of these spectra shows that for frequencies above about 1 kHz, the amplitude of these frequencies is already at least 30 dB less than the maximum 1 Hz band amplitudes in the spectrum. Also, this difference in source level is increasing at a rate of about 30 dB per octave of frequency as the frequencies increase. Therefore, the acoustic modeling used in this analysis used 1 kHz as the upper frequency of the band of frequencies modeled acoustically. Additionally, since there is some indication that many marine mammals integrate signals in one-third (1/3rd) octave bands (Richardson et al., 1995; DoN, 1998; and DoN, 2001b), it was reasonable to use a 1/3rd octave band analysis, or division, of the airgun's broadband signal based on the American National Standard Institute (ANSI) definitions for acoustic frequencies up to 1 kHz. (ANSI, 1984, 1986, and 2004).

2.4.5.2 Model Handling of the Broadband Seismic Signal

For each of the four sites identified in Table A-5 as representative of the acoustic propagation in the Gulf of Mexico, a set of acoustic model runs was made to be used in predicting the potential acoustic impact for each of the seismic survey types with AIM. Each of these model runs used the acoustic and model parameters identified above for all 1/3rd octave bands below 1 kHz, and for an azimuthal resolution of 15°. Essentially, for each azimuthal resolution, the 1/3rd octave band TL was calculated, and was then subtracted from the corresponding 1/3rd octave band

source level to determine the $1/3^{\text{rd}}$ octave band received levels for all depths and ranges along that bearing. Once all of the $1/3^{\text{rd}}$ octave band RLs were calculated, they were coherently added to derive the total broadband signal for all depths and ranges along that bearing. This broadband RL for each azimuth would then be used in the AIM modeling. In this way, any frequency-dependent propagation characteristics of the environment were correctly accounted for in the modeling. For example, during the modeling effort, it was recognized that some near-surface ducting or trapping was occurring for frequencies above about 600 Hz. And, even though the source level for these frequencies was 15-20 dB less than those at 50 to 100 Hz (i.e., the highest spectrum source levels) the reduced TL for the ducted frequencies out at ranges greater than 10 km (5.4 nmi), caused those frequencies to dominate the RL at shallow depths for ranges greater than about 10 km from the sources. This modeling methodology accounted for these types of affects.

2.4.6 Discussion of the Tolstoy et al. (2004, 2009) Results and Their Applicability to Shallow Water Seismic Transmission Loss

2.4.6.1 Introduction

Recently, two papers by Tolstoy et al. (2004, 2009) have reported measured transmission loss (TL) in several specific sites in the Gulf of Mexico for seismic airgun arrays in both shallow and deep waters. With the data provided and the methods that these papers use to characterize and present the data, it appears that TL for seismic sources in shallow water has been and is being over-estimated. That is, if deep water TL methodology, like $TL = 20 \times \text{Log}(\text{Range})$ [i.e., spherical spreading], is employed and even though these assumptions appear to give reasonable and measurable results in deep water, when they are applied to shallow water, the resulting TL estimate appears to be too high. Thus, the actual distance to a particular seismic airgun sound level isopleth in shallow water is greater than that predicted from using the deep water methodology. For example, Tolstoy et al. (2004) states that TL ranges to the 160 dB isopleths for measured deep water situations are between about 1.5 and 2.5 km while, in shallow water, these ranges increase to between 7 and 12 km. Given this example, clearly something must be done to account for the lower TL in shallow water if correct estimates of potential impacts to marine mammals near these sources are to be made.

2.4.6.2 Measured TL Variability in Shallow Water

One of the principle difficulties or issues with this approach is the general characterization of the measured data by Tolstoy et al. (2004, 2009), as either “shallow” or “deep.” Tolstoy et al. (2004) measurements were made in Gulf of Mexico waters approximately 30 m deep; while Tolstoy et al. (2009) data were from Gulf of Mexico waters approximately 40-60 m deep.² After

² The global oceanographic community typically considers waters less than 200 m deep as “shallow water,” and analyses using the AIM model used this value. In recent environmental compliance documentation for seismic airgun operations, Lamont-Doherty Earth Observatory of Columbia University has used 100 m depth as the cutoff for “shallow water.”

an examination of Figures 6 through 9 in Tolstoy et al. (2009), it is fairly obvious that the variability of TL as a function of range is greater for the measured shallow water data than the deep water data, especially when the Sound Exposure Levels (SELs) are compared. Since these data were collected by driving the source around the receivers, either in rough circles or in opening or closing spirals, much of this variability is due to the azimuthal variability of the measured TL, even when the range between the source and receivers was constant. There is always some variability in measured TL data (especially sound pressure level [SPL] data), which is caused by slight movements of sources and receivers in the water column, the direction or shape of source and receiver beams, wave motion, internal waves, and numerous other inhomogeneities of the ocean, both temporal and spatial. However, the measured deep water SEL data in Figure 7 Tolstoy et al., (2009), show considerably less azimuthal dependence (i.e., variability in TL typically of about 2-3 dB for any given range) than the shallow water data in Figure 9 of the same paper (i.e., about 6-9 dB for any given range). This higher variability of the TL in shallow water seems to be due to the variability of the bottom bathymetry and sediment, both as a function of range and azimuth, rather than the smaller variability introduced by the water column, even in deep water. This is probably at least partially due to the fact the even slight changes in bathymetry, while practically unnoticed in deep water, can cause significant changes in TL in shallow water. For example, a 20 m change of bathymetry in deep water, say, for water 2000 m deep, is not expected to change TL much, but in shallow water that is only 50 m deep, a sand bar or similar feature that can easily cause this magnitude of depth change will greatly change the TL of the signal as it passes over that feature.

2.4.6.3 Inherent Difficulties of Measuring and Estimating TL in Shallow Water

The difficulty of both measuring and estimating TL in shallow water has long been known to underwater acousticians. And this problem is further complicated in environmental compliance analyses because it is almost always necessary to estimate potential impacts to marine animals over large areas where bathymetry, bottom sediments, seasons, freshwater runoff, local currents, and weather conditions are constantly in flux. A good example of this variability is the expected difference between the shallow water location measured in Tolstoy et al. (2004) which appears to be in the sand-covered shelf (DoN, 2007c) south of the Alabama/Florida border and an area just 100 km to the west-southwest of where the outflow from the Mississippi River has deposited clays and silty-clay on the continental shelf (DoN, 2007c). The absorption of seismic acoustic energy in the clays and silts would be expected to be much higher than the sand, and the TL here would be greater. So, the question remains of how to reasonably represent the TL for a given area while also acknowledging, examining, and accounting for these numerous environmental variables, and still capturing the overall effects of the proposed action or seismic airgun operations on the environment.

The overall approach and data provided in the Tolstoy et al. (2004, 2009) papers allows one to attempt to quantify the shallow water TL for the sites measured without a complete understanding of the propagation present in those sites. For example, neither paper provides the actual sound velocity profile (SVP) for that site nor how it changes for the ranges and area covered. Hypothetically, the apparent lower TL measured in the shallow water areas could be caused by a strong surface duct that has trapped the near-surface acoustic energy, and has nothing to do with the bottom. Tolstoy et al. (2009) does mention some near-surface warming of

the SVP and a general downward refraction caused by this, but since those measurements occurred during the winter months (December, January and February), this could be just a local effect.

Based on the GDEM database (OAML, 2002) (Figure A-18), most of the historical SVP data for the shallow water in the Gulf of Mexico shows an iso-velocity profile throughout the year, with some near-surface warming in the late spring and summer months. In general, if the SVP is slightly downward-refracting, this would tend to cause the signal from near-surface sources, like seismic airgun arrays, to refract toward the ocean bottom and increase the incident angles at which they interact with the bottom. Since higher incident angles generally mean more penetration of the sound energy into the bottom and/or more scattering loss as the signal is reflected from the bottom, the overall TL for a downward-refracting environment would be expected to be greater than for the iso-velocity environment, where there is little or no refraction.

2.4.6.4 *Gulf of Mexico Shallow Water Propagation Sub-categories*

This discussion will now concentrate on the iso-velocity or near iso-velocity situation, since it would generally have less TL than the alternatives and it appears to be the most common historical propagation SVP in the shallow water of much of the Gulf of Mexico. In general, shallow water sound propagation has often been broken into three sub-categories (Figure A-26):

- Cross-slope (i.e., where the depth of water along the track of propagation remains about the same as the sound radiates outward from the source),
- Up-slope (i.e., where the sound moves into progressively shallower water), and
- Down-slope (i.e., where the sound moves into progressively deeper water).

Cross-slope propagation: For this situation, the ocean surface and bottom can act as a channel or duct and trap the acoustic energy between these two, roughly parallel boundaries. Also, if the ocean is calm and there is a highly reflective bottom (e.g., a sandy bottom), these azimuths from the source can act very much like a duct (i.e., there will be spherical spreading to the bottom of the duct [the ocean bottom] then cylindrical spreading [$10 \times \text{Log}(\text{Range})$] once the water column is filled and little loss through the ocean surface and bottom boundaries).

Up-slope propagation: For this situation, each interaction or reflection from either the bottom or the ocean's surface as the signal propagates outward from the source toward shore and shallower water, causes the incident angle to the bottom to become slightly more vertical (Urick, 1985). Generally, this causes each subsequent bottom reflection to have a higher loss than the previous one and to move a shorter distance from the source on each subsequent reflection. This is based on the principle that the incident and reflected angles for a sound reflecting off a surface are equal (Figure A-27, where these equal angles are labelled as " α ", " β ", and " ϵ "). Also note in this figure that each incident angle with the bottom increases as the ray moves toward shore. Therefore, up slope propagation definitely has greater loss than cross-slope propagation.

Down-slope propagation: This situation allows the acoustic energy to spread out into a larger water column as the acoustic ray moves into deeper water than that at the source's location. This

allows the acoustic energy to spread out faster than in the duct-like cross-slope case. Thus, a down-slope situation would also be expected to have more loss than the cross-slope case. Additionally, if the SVP is slightly downward refracting, the acoustic energy will tend to stay closer to the ocean bottom, which is typically further away from those marine mammals that are shallow divers and remain near the surface for the majority of the time.

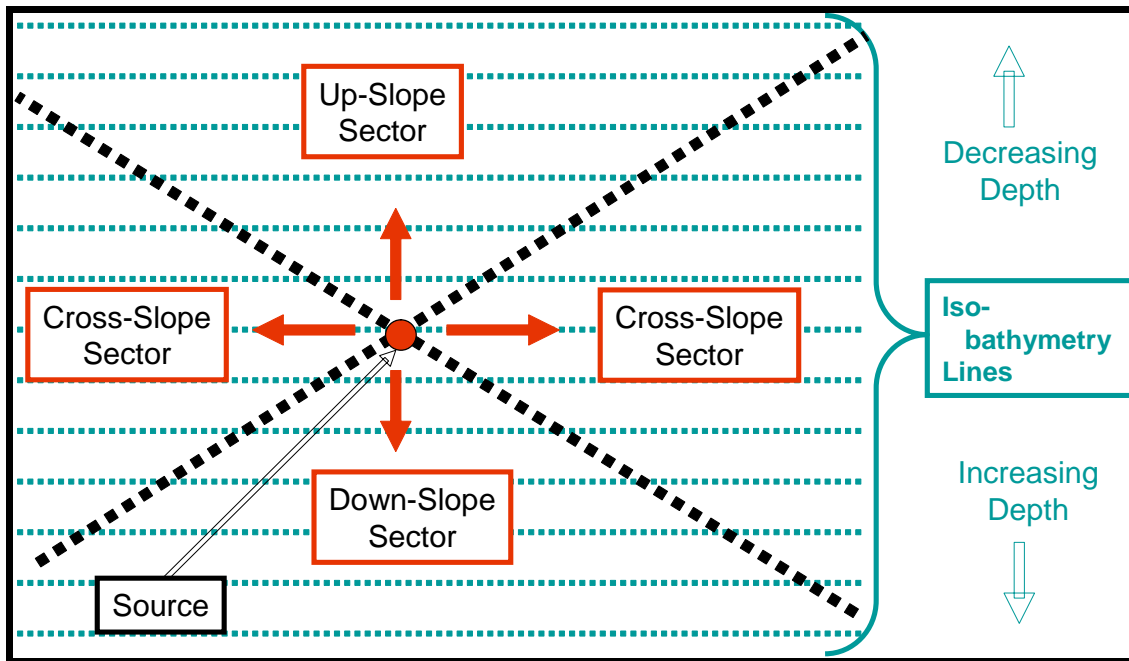


Figure A-26. Simplified geometry of shallow water propagation sub-categories.

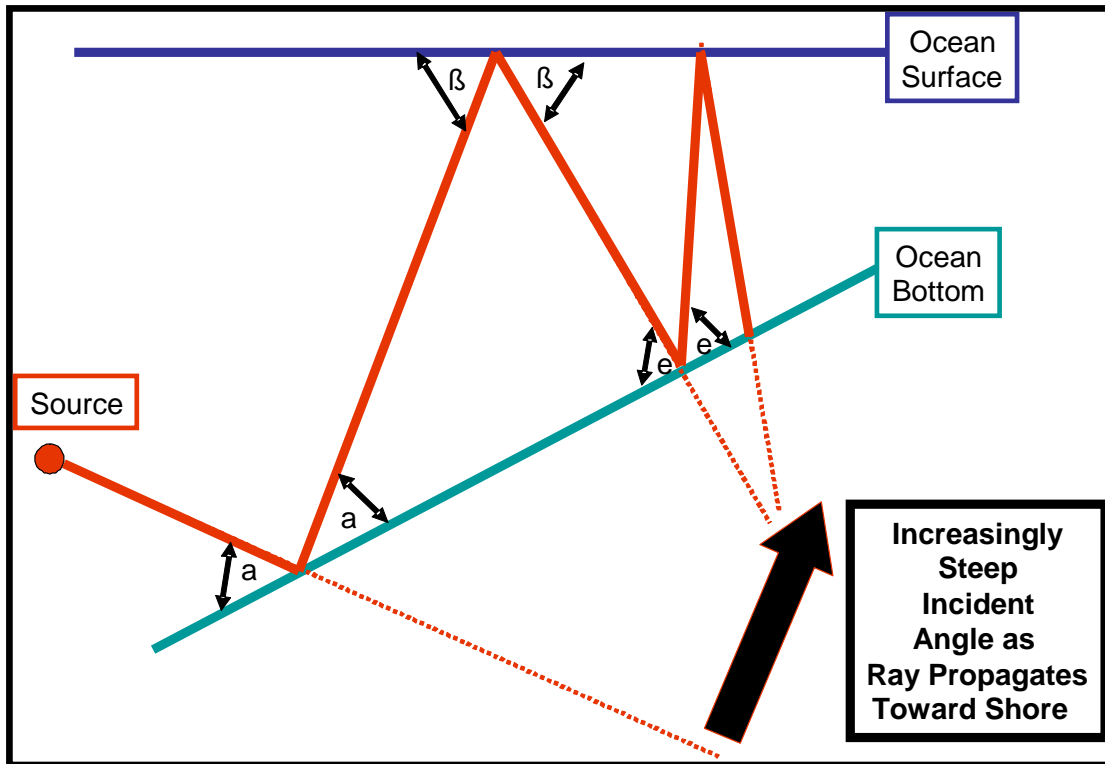


Figure A-27. Simplified geometry of the up-slope propagation sub-category.

2.4.6.5 *Methods of Estimating Shallow Water TL from Seismic Airguns in the Gulf of Mexico*

An examination of the shallow water Received Level (RL) plots in Tolstoy et al. (2004, 2009) show that for any given range from the source, the variance of the shallow water RL values are generally much larger than for the deep water values. Essentially, in the shallow water plots, Tolstoy et al. have combined all three sub-categories: cross-slope, down-slope and up-slope. Tolstoy et al. (2009) analyze these data and then uses a least-squares fit³ and 95th-percentile⁴ values to draw representative RL curves or equations. These equations are then used to determine ranges to the various isopleths. And in doing this, Tolstoy et al. (2009) is essentially using RL to represent TL, with assumptions about the source and the relationship “RL = SL – TL.” Although this is a conservative approach, the difficulty with it is that effectively the entire TL for the shallow areas are now probably being estimated by the cross-slope subcategory. This would have the lowest TL of any of the azimuthal bearings from the source. Further, depending on the slope in the area (which will cause changes to the widths of the various sectors in Figure A-26) and the potential presence of other small bottom features (which are typically present during the measurements but may be too small to appear in bathymetry data), a case could be

³ Least-squares fit is a mathematical procedure for finding the best-fitting curve to a given set of points by minimizing the sum of the squares of the offsets (“the residuals”) of the points from the curve.

⁴ 95th percentile is the value of the variable below which 95 percent of the observations fall.

made that this approach will estimate the lowest TL in that area for any given range even if it only occurs for a small number of azimuths. This occurs because most of the measurements in shallow water were conducted by driving the source on a spiral or sometimes circular track around the receivers, thus effectively sampling each range as discussed.

The approach used to predict the potential impacts used by AIM in this document does not use this methodology. By estimating TL for each 1/3rd octave frequency bin and for each 15 degrees of azimuth, the AIM approach provides a more thorough sampling and, therefore, a better representation of the variety of cases which will probably be encountered in the Gulf of Mexico, particularly in shallow water areas. It can also be argued that AIM better statistically represents the overall local underwater sound propagation, with its variances, while still capturing the situations where animals can be affected out to longer ranges.

2.4.6.6 Seismic Airgun Beampattern Issues in Shallow Water

Seismic Airgun Array Example Specifications
Ship: R/V <i>Marcus G. Langseth</i> is a 235 ft, 2,578 gross ton research vessel, owned by the National Science Foundation and operated by Lamont-Doherty Earth Observatory of Columbia University.
<p style="text-align: center;">Airgun Array</p> <ul style="list-style-type: none"> • Energy source: thirty-six 1900 psi Bolt Technology Corp. airguns of 40-360 in³. <ul style="list-style-type: none"> • Four strings, each containing nine operating airguns. • Source output (downward): 0-peak is 84 bar-m (259 dB re 1 μPa at 1 m).

Another facet of the potential issues with applying the measured results from Tolstoy et al. (2004, 2009) is the issue that in shallow water, and for the lower frequencies (i.e., for frequencies between, say, 50 and 500 Hz) that the beams produced by these seismic airgun arrays (which are tuned for deep water) have not fully formed and the bottom is encountered while the beam pattern is still in the “near-field.” This greatly complicates how the acoustic energy is projected from the source outward. Evidence of this effect can be seen in Figures 8 and 9 of Tolstoy et al. (2009) in the variability of the TL data for ranges less than 1 km from the array.

An examination of the deep water data in Figures 6 and 7 in Tolstoy et al. (2009) show that at about 1 km, the average SPL RMS RL is about 172 dB, while the SEL RL is about 162 dB. If a 60 dB TL in the first km (spherical spreading) is assumed from a point source, then the deep water source levels (SL) are about 132 dB re 1μPa @ 1m and 122 dB re 1 μPa²-s @ 1 m, for the SPL RMS and SEL values, respectively. Since the beams did not completely form in the shallow water before interacting with the ocean bottom, it is anticipated that less energy is directed downward and more energy projects out horizontally into the water column. An examination of Figures 8 and 9 in Tolstoy et al. (2009) at about 1 km indicate that this effect raises the effective SL values by about 12 to 15 dB.

Furthermore, there does not appear to be very much difference between the RLs measured by inline or crossline seismic airgun shots in the variability of the data in shallow water, which further shows that the near-field inclusion of the ocean bottom disrupts the beamforming.

2.4.6.7 Significance of the Assumptions Built into the Tolstoy et al. (2004, 2009) Papers

A final significant issue with applying the results from Tolstoy et al. (2004, 2009) as a prediction of TL in shallow water is in the nature of the Tolstoy measurements. Specifically, these papers report the RLs for the R/V *Marcus G. Langseth* airgun array in two shallow water locations. The resulting RL data and curve fits, therefore, should be applicable in predicting RL values for that specific array in those locations, or possibly for other locations with similar propagation characteristics (e.g., water depth, bathymetric characteristics, SVP, bottom sediment type and depths, etc.). Additionally, these curves are limited in range covered, and actually are fitted to data between about 1 to 17 km. Thus, if any of these assumptions or implied assumptions are violated, care must be taken in any attempt to apply these curves elsewhere.

One of the embedded or hidden assumptions in the application of these curves concerns the SL of the airgun array, which is of extreme importance. The use of this term alone implies that the nominal source for this PEIS could be characterized by a point source with a SL and a beam pattern. However, as has been discussed above, in the shallow water sites, the ocean bottom is encountered before the beam is fully formed (i.e., the ocean bottom is in the “near-field” of the airgun array). Therefore, a representative point source (with accompanying beam pattern) is not easily identified, and it is highly dependent on various parameters (e.g., the water depth below the source, sediment type and slope, etc.), which were changing constantly during the Tolstoy et al. measurement efforts.

An example of the significance of this effect is the following calculation. Based on the previously identified characteristics of the *Langseth* array, the actual RMS SL can be estimated at about 249 dB re 1 μPa at 1 m (i.e., about 10 dB less than the zero-to-peak SL value). Additionally, assuming that the *Langseth* array would have a far-field spectrum similar to that of the modeled nominal array used in this PEIS, the SEL SL for the *Langseth* array would be about 239 dB re 1 $\mu\text{Pa}^2\text{-s}$ at 1 m (i.e., about 10 dB less than the RMS SL value, with the correct units). Based on these estimated SLs and the intercepts at one kilometer for the Tolstoy et al. (2009) curve fits, Table A-6 shows the estimated TL that is encountered during the first kilometer from the airgun array. As an example, the RMS “least squares fit” curve experiences 68.15 dB TL in the first kilometer (e.g., $\text{TL} = \text{SL} - \text{RL}$ or $249 - 180.85 = 68.15$ dB). This equates to 22.7 times the log of range (i.e., $\text{TL} = X \times \text{Log}[R]$ or $68.15 = X \times \text{Log}[1000]$ or $X = 68.15/3 = 22.7$). In every case, this TL is greater than one would expect from purely spherical spreading (i.e., $60 \text{ dB} = 20 \times \text{Log}[1,000]$). This is as expected because, even though the beams are not fully formed, the sound transmitted from the array is generally directed downward, interacting strongly with the bottom and probably losing energy into the bottom. Additionally, the interference with the beam formation also causes an effective lowering of the airgun array’s SL. This is because not all of the components of the airgun array can contribute effectively and efficiently to the correct formation of the beam, as the airgun array was designed for. This is a classic example of an undesirable near-field phenomenon.

Table A-6 Estimated TL in the First Kilometer for Shallow Water

	RL at 1 km		TL in the first km	
	RMS RL	SEL RL	RMS TL	SEL TL
95th % Fit	183.62	175.84	65.38	63.16
Least-Squares Fit	180.85	172.84	68.15	66.16

Table A-7 provides the estimated TL in the first kilometer from the curve fit equations in Tolstoy et al. (2009). Additionally, the difference error between the two estimated TLs (i.e., from estimating the SLs vice using the curve fit equations to estimate TL) is provided in Table A-7. These error values show that by using the Tolstoy et al. (2009) curve fit equations alone to estimate the overall TL, the actual TL in just the first kilometer is underestimated by as much as 8.38 and 14.92 dB, depending on which metric (RMS or SEL) and which curve fit (95th % fit or least-squares fit) are used. Therefore, if the airgun source used is different from that of the *Langseth's*, this difference must be accounted for, or the ranges to the 160, 180, and 190 dB isopleths will be incorrect. Generally, if the SL for an array is less than that of the *Langseth's* (i.e., in the case for the nominal array identified for analysis), the ranges will be overestimated, while the range for larger arrays may be underestimated.

Table A-7 Estimated TL in the First Kilometer of Shallow Water Based on Tolstoy et al. (2009) Curve Fit Equations

	TL in the first km Based on Tolstoy (2009) curve fit equations		Difference Error	
	RMS TL	SEL TL	RMS	SEL
95th % Fit	57.00	51.24	8.38	11.92
Least-Squares Fit	57.00	51.24	11.15	14.92

As a simple example of the effect of this issue, we will examine the RMS ranges to the 160 and 180 dB isopleths for this nominal array, using the uncorrected Tolstoy et al. (2009) equation with the “least-squares fit” equation and a corrected Tolstoy et al. (2009) equation. For the corrected approach, the nominal array’s SL is: a) increased by 20 dB to account for the fact that it is assumed to be a point source (see Appendix C of the PEIS), b) decreased by 20 dB to account for the horizontal array effect (and see Appendix C of the PEIS), c) the actual SL (i.e., 230 dB_{RMS} vice the 249 dB_{RMS} Tolstoy et al. [2009] uses), and d) experiencing 68.1 dB or $22.7 \times \text{Log}(R)$ TL in the first kilometer. Thus, the nominal array’s RMS SL is about 230 dB re 1 μPa at 1 m, or about 19 dB less than the Langseth array. Table A-8 shows the ranges to the 160 and 180 dB isopleths for both approaches. By underestimating the TL in the first kilometer, and by overestimating the nominal array’s SL (i.e., assuming it is 19 dB higher and equal to the Langseth array), the Tolstoy et al. (2009) equations overestimate the distance to the 160 and 180 dB isopleths for this nominal array.

Table A-8 Range to Shallow Water 160 and 180 dB Isopleth by Two Methodologies

	Range (km)		
	Using Tolstoy Least-Squares Fit Equation	Tolstoy Corrected for: 1) SL difference and 2) TL in the first km	Deep Water Approximation
180 dB Isopleth	1.4	0.13	0.3
160 dB Isopleth	12.5	1.26	3.0

Finally, it should be pointed out that the corrected values for the shallow water 160 and 180 dB isopleths for this nominal array (Table A-8) are approximately half of the value derived for deep water. These deep water values assume: 1) spherical spreading throughout the propagation process, and 2) a 20 dB loss to airgun array hypothetical SL_{RMS} for horizontal propagation of the transmitted airgun signal (MMS, 2004). Therefore, the strict and uncorrected application of the Tolstoy et al. (2009) least-squares fit equation for RMS data is still extremely conservative. That is, there is a difference of over 400% and approximately 300%, respectively, for the Level A and B isopleths, when compared to the deep water approximations. They are off by about 1,000%, when compared to the corrected Tolstoy et al. values, and therefore, should not be used.

2.4.6.8 *Recommended Methodology for Estimating Shallow Water TL*

Historically, there are four methods of estimating the TL for a shallow water area. They are: 1) dedicating resources (i.e., ships, planes, sources and sensors) to actually measure the in-situ TL for the site; 2) use the best available scientific databases (i.e., for bathymetry, SVPs, sediment type and structure, etc.) and models (i.e., acoustic propagation models capable of deriving a TL estimate for the depths, source frequencies, and bottom characteristic present) to predict the TL; 3) estimating the TL by intelligently extrapolating from a set of empirical data; or 4) estimating the shallow water TL without any empirical data, but considering the applicability of some basic properties of the physics of acoustics (e.g., assuming no absorption at the ocean surface and bottom, and using spherical spreading out to a range equal to water depth at the source followed by cylindrical spreading for ranges beyond that). In general, and as a first estimate, these methodologies are probably in order of decreasing accuracy. Additionally, it must be remembered that each of these approaches has its limitations. For example, even though measuring the TL may be the most accurate and reliable, it requires calibrated equipment, significant time and money expenditures, and it only captures a limited amount of data. Thus, different bearings from the source, different source water depths (to adjust for a moving source's TL), different seasons, etc., are not directly available from this method.

The issue of characterizing shallow water TL has been recognized and investigated for many years. And the advantage of using a generalized equation (i.e., as in methodology 4 above) and calibrating it with data (i.e., into equations that fall under methodology 3) has been accomplished in the Mediterranean Sea (Hastrup and Akal, 1980). In this memorandum, the authors generalize shallow water with the following equation:

$$TL = 15 \times \log(R) + \{A + B \times (\log(f)) + C \times (\log^2(f))\} \times R + D, \text{ in dB}$$

Where: A, B, C, and D are constants, based on local conditions,
f = frequency (Hz), and
R = range (m).

The authors further state that they have applied this equation to about ten different Mediterranean Sea sites for non-pulse sonars in areas where extensive TL measurements have been made. However, that quality of TL data does not exist yet for airgun arrays in the Gulf of Mexico, and the airgun source, which has a broadband signal, may significantly complicate this approach. For example, there is not just one value for the “f” term, so the question remains of which frequency(ies) should be used? Thus, further analysis with this approach is beyond the scope and time constraints of this petition.

Based on the need to complete an analysis in support of an EA or EIS, before any dedicated measurements can be completed, methodology 1 above is generally impractical for this case. Similarly, methodology 4, which typically has limited scientific data to support its assumptions, is also undesirable for EA or EIS use, unless there is no other method available. Therefore, methods 2 and 3 appear to be the best approaches. The AIM methodology and approach used to model and estimate potential impacts, as discussed here, follows methodology 2. Methodology 3 is approximated by applying calibrations for an airgun’s SL and the TL in the first kilometer to the curve fit equations in Tolstoy et al. (2009) to derive a calibrated equation of TL for shallow water of depth, SVP and bottom properties similar to those observed in Tolstoy et al. (2009).

The recommended methodology to calibrate the Tolstoy et al. (2009) shallow water data is:

- Identify the SPL RMS SL in dB for the source to be used;
- Approximate the TL in the first kilometer from the source as
 $TL = 22.7 \times \text{Log}(r)$, where “r” is range in meters;
- Approximate the TL beyond the first kilometer from the source as
 $TL = 68.15 + 19.0 \times \text{Log}(R)$, where “R” is range in kilometers;
- Use the correct SPL RMS SL (i.e., the actual far-field RMS SL, which for the PEIS nominal array is 230 dB re 1 μPa @ 1 m RMS) which needs to be corrected for both the hypothetical point source correction of about +20 dB and the horizontal array correction of -20 dB; and
- Determine RL or ranges to 160 and 180 dB isopleths using the equation
 $RL = SL - TL$, where the appropriate TL from above is used.

Since these equations are based on the data collected in Tolstoy et al (2009) (i.e., they appear to be for an area where sand is the predominant bottom type, and sand is a highly reflective bottom), they will be conservative for most conditions, especially where the entire water column is ensonified and the actual bottom type is more absorbent (e.g., mud or silt). Care will still need to be taken if a duct is present, since these data were not collected in that type of propagation and the actual TL may not be very compatible with that measured by Tolstoy et al. (2009). Finally, if actual, reliable TL data are available for the site, it should be used to upgrade or better calibrate the Tolstoy et al. (2009) curve fit equations to that site.

2.5 MARINE MAMMAL DENSITIES

At the time of this analysis, the best available marine mammal density estimates for the Gulf of Mexico are the U. S. Navy's Navy OPAREA Density Estimates (NODE) database (DoN, 2007b). These density estimates are based on the National Marine Fisheries Services-Southeast Fisheries Science Center (NMFS-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 NODE database are four seasonal surface density plots of the Gulf of Mexico for each of the marine mammal species occurring there. Figures A-28 and A-29 are examples of these surface density plots for bottlenose dolphins in the summer and Pantropical spotted dolphins in the summer, fall and winter, respectively. The resolution or grid size in these plots is dependent on the amount of data available for each species. The density gradations are specific to each plot, but the higher value for each gradation is used in the subsequent analysis. Each of these figures has been overlaid with the boundaries of the nine acoustic model regions used in this analysis. For each of these nine regions, the average density was computed. The resulting densities are presented in Tables A-9 through A-12, for each species and season.

It should be noted that while the U.S. Navy was creating the NODE database, the NMFS was routinely consulted on the process, and provided much of the data on which the analysis is based and reviewed the resulting database. Additionally, the Gulf of Mexico data (along with similar NODE data for the east coast of the United States) were used in the Final EIS for Atlantic Fleet Active Sonar Training (DoN, 2008).

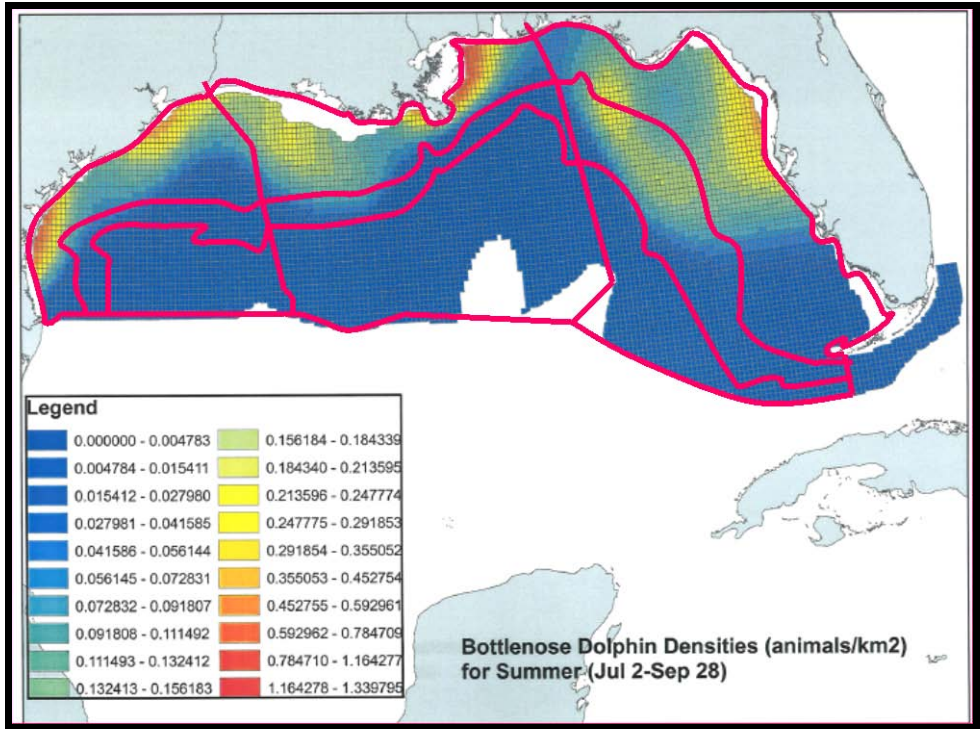


Figure A-28. NODE Bottlenose Dolphin Density Plot for Summer (DoN, 2007b).

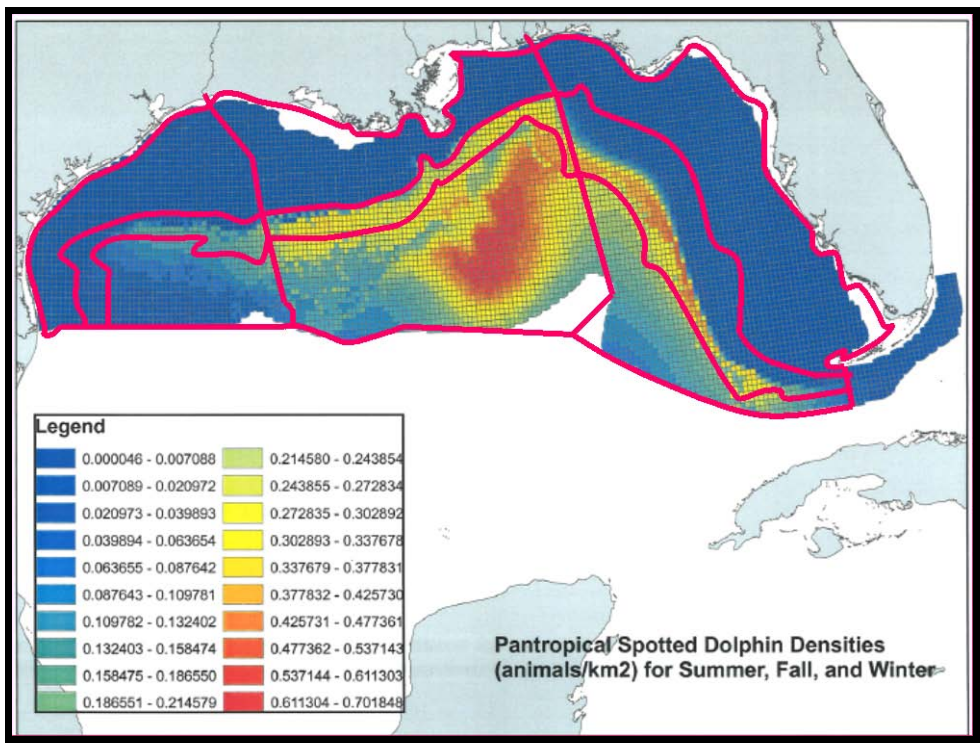


Figure A-29. NODE Pantropical Spotted Dolphin Density Plot for Summer, Fall and Winter (DoN, 2007b).

Table A-9. Gulf of Mexico Marine Mammal Densities (averaged by model site) for Spring (DoN, 2007b).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Marine Mammal Species									
<i>Mysticetes</i>									
Bryde's whale	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<i>Odontocetes</i>									
Atlantic spotted dolphin	0.2405	0.0367	0.0230	0.0155	0.0022	0.0155	0.0083	0.0022	0.0022
Beaked whales:	0.0002	0.0000	0.0000	0.0056	0.0047	0.0006	0.0035	0.0037	0.0015
Cuvier's									
Blainville's									
Gervais'									
Bottlenose dolphin	0.2032	0.2692	0.1452	0.2888	0.0713	0.0048	0.3887	0.0048	0.0048
Clymene dolphin	0.0023	0.0005	0.0005	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456
False killer whale	0.0001	0.0000	0.0000	0.0025	0.0026	0.0026	0.0027	0.0027	0.0027
Fraser's dolphin	0.0001	0.0001	0.0001	0.0025	0.0026	0.0026	0.0019	0.0019	0.0019
Killer whale	0.0350	0.0175	0.0175	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004
<i>Kogia</i> spp.	0.0000	0.0000	0.0000	0.0019	0.0016	0.0001	0.0037	0.0021	0.0004
Dwarf sperm whale									
Pygmy sperm whale									
Melonheaded whale	0.0009	0.0001	0.0001	0.0082	0.0086	0.0086	0.0091	0.0091	0.0091
Pantropical spotted dolphin	0.0426	0.0110	0.0110	0.2521	0.2505	0.1580	0.5317	0.5826	0.1225
Pygmy killer whale	0.0001	0.0000	0.0000	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011
Risso's dolphin	0.0001	0.0001	0.0001	0.0133	0.0130	0.0042	0.0115	0.0100	0.0051
Rough-toothed dolphin	0.0040	0.0038	0.0244	0.0043	0.0045	0.0030	0.0119	0.0067	0.0017
Short-finned pilot whale	0.0003	0.0001	0.0001	0.0060	0.0060	0.0060	0.0063	0.0063	0.0063
Sperm whale	0.0001	0.0001	0.0001	0.0033	0.0060	0.0025	0.0046	0.0049	0.0020
Spinner dolphin	0.0029	0.0004	0.0002	0.1724	0.2178	0.0000	0.0062	0.0726	0.0000
Striped dolphin	0.0003	0.0002	0.0001	0.0396	0.0511	0.0126	0.0236	0.0515	0.0191

Table A-10. Gulf of Mexico Marine Mammal Densities (averaged by model site) for Summer (DoN, 2007b).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Marine Mammal Species									
<i>Mysticetes</i>									
Bryde's whale	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<i>Odontocetes</i>									
Atlantic spotted dolphin	0.2405	0.0367	0.0230	0.0155	0.0022	0.0155	0.0083	0.0022	0.0022
Beaked whales:	0.0000	0.0000	0.0000	0.0010	0.0014	0.0010	0.0021	0.0024	0.0017
Cuvier's									
Blainville's									
Gervais'									
Bottlenose dolphin	0.1373	0.4734	0.1883	0.1034	0.0048	0.0048	0.0048	0.0048	0.0048
Clymene dolphin	0.0023	0.0005	0.0005	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456
False killer whale	0.0001	0.0000	0.0000	0.0025	0.0026	0.0026	0.0027	0.0027	0.0027
Fraser's dolphin	0.0001	0.0001	0.0001	0.0025	0.0026	0.0026	0.0019	0.0019	0.0019
Killer whale	0.0350	0.0175	0.0175	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004
<i>Kogia</i> spp.	0.0000	0.0001	0.0000	0.0002	0.0019	0.0000	0.0028	0.0061	0.0042
Dwarf sperm whale									
Pygmy sperm whale									
Melonheaded whale	0.0009	0.0001	0.0001	0.0082	0.0086	0.0086	0.0091	0.0091	0.0091
Pantropical spotted dolphin	0.0071	0.0071	0.0071	0.1986	0.2316	0.1432	0.3738	0.3285	0.2041
Pygmy killer whale	0.0001	0.0000	0.0000	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011
Risso's dolphin	0.0001	0.0001	0.0001	0.0133	0.0130	0.0042	0.0115	0.0100	0.0051
Rough-toothed dolphin	0.0040	0.0038	0.0244	0.0043	0.0045	0.0030	0.0119	0.0067	0.0017
Short-finned pilot whale	0.0003	0.0001	0.0001	0.0060	0.0060	0.0060	0.0063	0.0063	0.0063
Sperm whale	0.0001	0.0001	0.0001	0.0033	0.0060	0.0025	0.0046	0.0049	0.0020
Spinner dolphin	0.0029	0.0004	0.0002	0.1724	0.2178	0.0000	0.0062	0.0726	0.0000
Striped dolphin	0.0003	0.0002	0.0001	0.0396	0.0511	0.0126	0.0236	0.0515	0.0191

Table A-11. Gulf of Mexico Marine Mammal Densities (averaged by model site) for Fall (DoN 2007b).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Marine Mammal Species									
<i>Mysticetes</i>									
Bryde's whale	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<i>Odontocetes</i>									
Atlantic spotted dolphin	0.2405	0.0367	0.0230	0.0155	0.0022	0.0155	0.0083	0.0022	0.0022
Beaked whales:	0.0000	0.0000	0.0000	0.0010	0.0014	0.0010	0.0021	0.0024	0.0017
Cuvier's									
Blainville's									
Gervais'									
Bottlenose dolphin	0.2032	0.2692	0.1452	0.2888	0.0713	0.0048	0.3887	0.0048	0.0048
Clymene dolphin	0.0023	0.0005	0.0005	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456
False killer whale	0.0001	0.0000	0.0000	0.0025	0.0026	0.0026	0.0027	0.0027	0.0027
Fraser's dolphin	0.0001	0.0001	0.0001	0.0025	0.0026	0.0026	0.0019	0.0019	0.0019
Killer whale	0.0350	0.0175	0.0175	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004
<i>Kogia</i> spp.	0.0000	0.0001	0.0000	0.0002	0.0019	0.0000	0.0028	0.0061	0.0042
Dwarf sperm whale									
Pygmy sperm whale									
Melonheaded whale	0.0009	0.0001	0.0001	0.0082	0.0086	0.0086	0.0091	0.0091	0.0091
Pantropical spotted dolphin	0.0071	0.0071	0.0071	0.1986	0.2316	0.1432	0.3738	0.3285	0.2041
Pygmy killer whale	0.0001	0.0000	0.0000	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011
Risso's dolphin	0.0001	0.0001	0.0001	0.0133	0.0130	0.0042	0.0115	0.0100	0.0051
Rough-toothed dolphin	0.0040	0.0038	0.0244	0.0043	0.0045	0.0030	0.0119	0.0067	0.0017
Short-finned pilot whale	0.0003	0.0001	0.0001	0.0060	0.0060	0.0060	0.0063	0.0063	0.0063
Sperm whale	0.0001	0.0001	0.0001	0.0033	0.0060	0.0025	0.0046	0.0049	0.0020
Spinner dolphin	0.0029	0.0004	0.0002	0.1724	0.2178	0.0000	0.0062	0.0726	0.0000
Striped dolphin	0.0003	0.0002	0.0001	0.0396	0.0511	0.0126	0.0236	0.0515	0.0191

Table A-12. Gulf of Mexico Marine Mammal Densities (averaged by model site) for Winter (DoN, 2007b).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Marine Mammal Species									
<i>Mysticetes</i>									
Bryde's whale	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<i>Odontocetes</i>									
Atlantic spotted dolphin	0.2405	0.0367	0.0230	0.0155	0.0022	0.0155	0.0083	0.0022	0.0022
Beaked whales:	0.0000	0.0000	0.0000	0.0010	0.0014	0.0010	0.0021	0.0024	0.0017
Cuvier's									
Blainville's									
Gervais'									
Bottlenose dolphin	0.2032	0.2692	0.1452	0.2888	0.0713	0.0048	0.3887	0.0048	0.0048
Clymene dolphin	0.0023	0.0005	0.0005	0.0456	0.0456	0.0456	0.0456	0.0456	0.0456
False killer whale	0.0001	0.0000	0.0000	0.0025	0.0026	0.0026	0.0027	0.0027	0.0027
Fraser's dolphin	0.0001	0.0001	0.0001	0.0025	0.0026	0.0026	0.0019	0.0019	0.0019
Killer whale	0.0350	0.0175	0.0175	0.0003	0.0003	0.0003	0.0004	0.0004	0.0004
<i>Kogia</i> spp.	0.0000	0.0001	0.0000	0.0002	0.0019	0.0000	0.0028	0.0061	0.0042
Dwarf sperm whale									
Pygmy sperm whale									
Melonheaded whale	0.0009	0.0001	0.0001	0.0082	0.0086	0.0086	0.0091	0.0091	0.0091
Pantropical spotted dolphin	0.0071	0.0071	0.0071	0.1986	0.2316	0.1432	0.3738	0.3285	0.2041
Pygmy killer whale	0.0001	0.0000	0.0000	0.0010	0.0010	0.0010	0.0011	0.0011	0.0011
Risso's dolphin	0.0001	0.0001	0.0001	0.0133	0.0130	0.0042	0.0115	0.0100	0.0051
Rough-toothed dolphin	0.0040	0.0038	0.0244	0.0043	0.0045	0.0030	0.0119	0.0067	0.0017
Short-finned pilot whale	0.0003	0.0001	0.0001	0.0060	0.0060	0.0060	0.0063	0.0063	0.0063
Sperm whale	0.0001	0.0001	0.0001	0.0033	0.0060	0.0025	0.0046	0.0049	0.0020
Spinner dolphin	0.0029	0.0004	0.0002	0.1724	0.2178	0.0000	0.0062	0.0726	0.0000
Striped dolphin	0.0003	0.0002	0.0001	0.0396	0.0511	0.0126	0.0236	0.0515	0.0191

2.6 ACOUSTIC INTEGRATION MODEL[®] (AIM) Modeling

2.6.1 Introduction to AIM

To estimate how changing the acoustic source characteristics affects the acoustic exposure of animals, the Acoustic Integration Model[®] (AIM) was utilized (Frankel et al., 2002). AIM is a Monte Carlo-based statistical model, strongly based on two earlier models: a whale movement and tracking model developed for the census of the bowhead whale (Ellison et al., 1987), and an underwater acoustic back-scattering model for a moving sound source in an under-ice Arctic environment (Bishop et al., 1987). Because the exact positions of sound sources and animals (sound receivers for the purpose of this analysis) in any given simulation cannot be known, multiple runs of realistic predictions are used to provide statistical validity. The movement and/or behavioral patterns of sources and receivers can be modeled based on measured field data, and these patterns can be incorporated into the model. Each source and/or receiver is modeled via the “animat” concept, where each has parameters that control its speed and direction in three dimensions. In the case of the source, it is also imbued with the parameters describing its source operation over time (i.e., SL, signal duration, and spectral characteristics). It is also possible to simulate the type of diving pattern that an animal exhibits in the real world. Furthermore, the movement of the animat can be programmed to respond to environmental factors, such as water depth and sound level (this latter feature was not used in this analysis). In this way, species that normally inhabit specific environments can be constrained in the model to stay within that habitat.

Once the behavior of the animats has been programmed, the model is run. The run consists of a user-specified number of steps forward in time. For each time step, each animat is moved according to the rules describing its behavior. For each time step of the model run, the received sound levels at each receiver (i.e., each marine mammal) animat are calculated. For this analysis, AIM returns the movement patterns of the animats, and the received sound levels are calculated separately, using the acoustic propagation predictions provided by the CASS/GRAB model.

At the end of each time step, each animat “evaluates” its environment, including its 3-D location, the time, and the received sound level (if anthropogenic sound is present). 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 to the environment. These responses to the environment are entitled ‘aversions’. There are a number of potential aversion variables that can be used to build an animat’s behavioral pattern.

Modeling simulations for four different survey types were run at four sites in the Gulf of Mexico. The starting locations and modeling specifics for each of these sites were provided above in Table A-5.

2.6.2 AIM Simulation of the Various Seismic Survey Types

For this assessment, the creation of each modeling simulation began with the creation of a movement pattern for the seismic source vessel representing a different survey type. The survey types included Ocean Bottom Seismic survey (OBS), 2-Dimensional, 3-Dimensional and Wide Azimuth surveys (WAZ). The parameters for each survey type are provided below in Table A-13 and are illustrated in Figures A-30 – A-33.

It should be noted that the actual source level range or the maximum source level used by each survey type is known to vary somewhat from the “nominal survey” modeled by AIM. The specific maximum source level used in the modeling effort is based on the level identified in the petition and grouped as shown in Table A-20. Section 2.6.7 explains how this correction is applied to the model results.

Table A-13. Seismic Vessel Parameters for AIM Simulations.

Survey Type	Leg Length (km)	Leg Spacing (km)	Number of Modeled Legs	Total Simulation Duration (min)	Shot Interval (seconds)
OBS	4.8	0.05	96	3,528	6
2D	168	3	8	10,400	15
3D	100	0.35	14	10,400	15
WAZ (four ships)	100	0.35	14	10,400	15 (per survey) 60 (per ship)
2D Hi-Res	50	0.30	~20	~ 16,632	~ 8

2.6.2.1 Ocean Bottom Seismic survey

AIM projects were written to simulate Ocean Bottom Seismic surveys (OBS). These were small in spatial extent to represent a single 4.8 x 4.8 km block. The legs were 0.05 km apart and 4.8 km long. The vessel speed was modeled at 8 km/h, with a shot interval of 6 seconds to provide a shot every 12.5 meters. The AIM step size was set to 15 seconds to ensure an accurate representation of source movement. This was necessary in part due to the close spacing of the lines. Essentially, the AIM modeling represents the OBS survey of a single block.

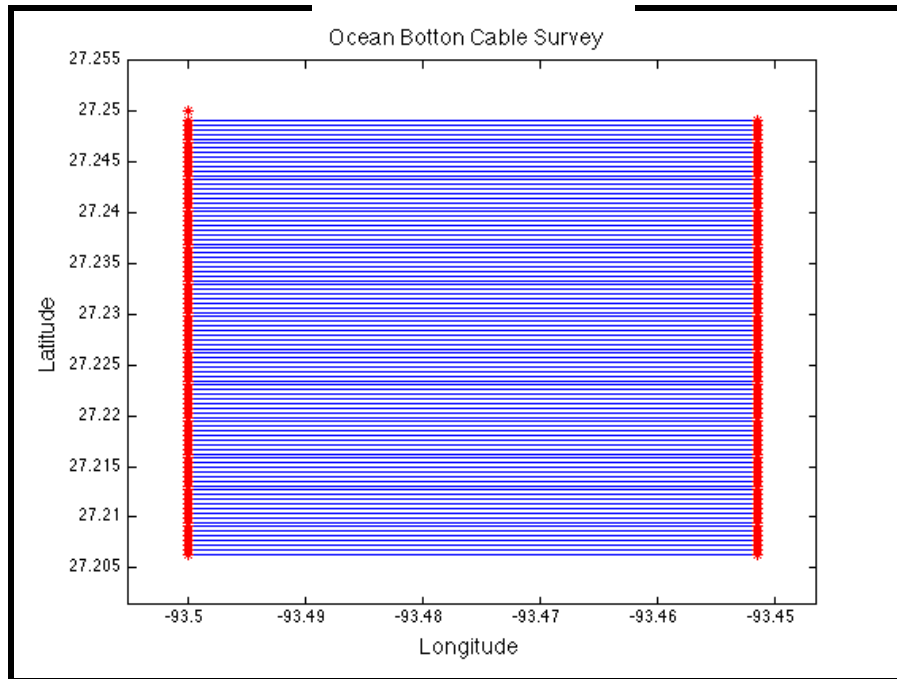


Figure A-30. Illustration of an Ocean Bottom Seismic Survey Source Pattern.

2.6.2.2 Two-Dimensional Survey

The lines for the two-dimensional survey were 166 km long, to simulate longitudinal coverage over a wide number of blocks. This is the equivalent area of about 173 blocks surveyed in the model run. The 8 lines were spaced at 3 km apart to simulate a latitudinal coverage of five blocks for the survey. The vessel speed was 8 km/h and shots were modeled every 15 seconds. The AIM model step size was 30 seconds.

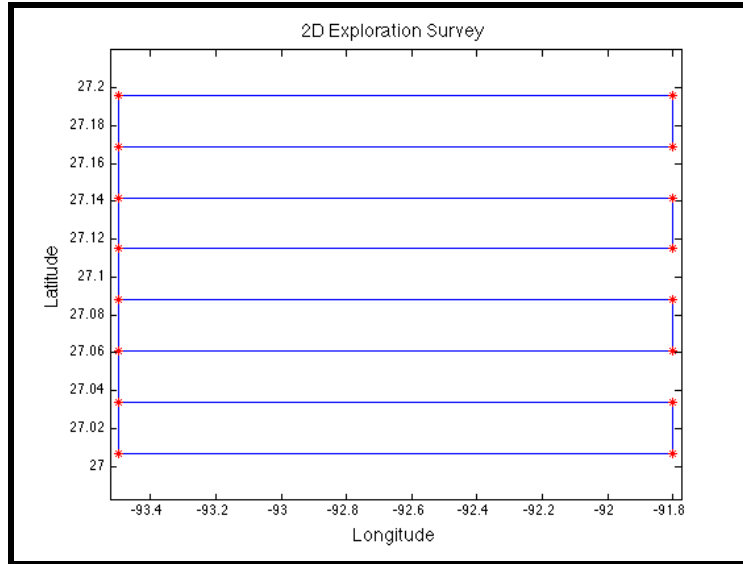


Figure A-31. Illustration of a Two-dimensional Survey Source Pattern.

2.6.2.3 Three-Dimensional Survey

A full 3-D survey might cover a width of 100 km (21 blocks) and a height of 24 km (five blocks). At a modeled speed of 8 km/h, this survey would require 52,867 minutes (~36 days). The AIM model was run for the same duration as the 2D survey (10,400 minutes). Thus, the modeled survey was 100 km wide and 4.8 km tall, for a total of about 21 blocks covered in a model run.

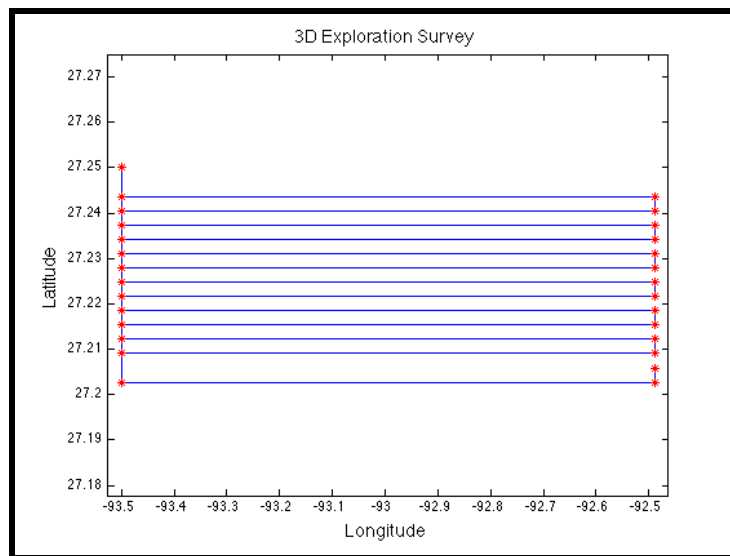


Figure A-32. Illustration of a Three-dimensional Survey Source Pattern.

2.6.2.4 *Wide Azimuth Survey*

Four ships were modeled for the Wide Azimuth Survey (WAZ). They formed a box 8 km long (parallel to the line) and 1 km wide (perpendicular to the line). Each ship was modeled to fire every 15 seconds. The WAZ survey was 100 km long, and had a line spacing of 0.6 km. The total duration of the simulation was 10,400 minutes, covering an area 100 km wide by 8.4 km tall, for a total of about 36.75 blocks covered in a model run.

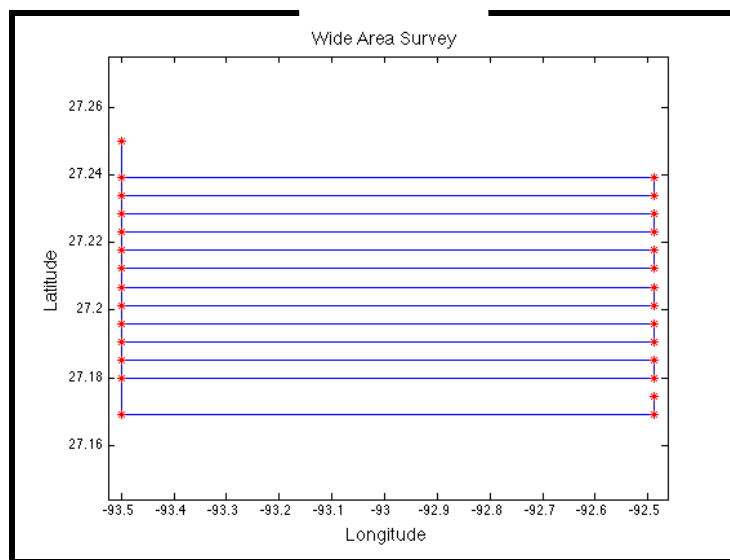


Figure A-33. Illustration of a WAZ Survey Source Pattern.

2.6.2.5 *2-D High-Resolution Survey*

A full 2-D High Resolution survey typically covers a block with 20 lines, with a spacing of about 300 m between lines. This equates to 96 km of survey tow per block, and takes about 2 days to complete per block. The AIM model was run for a survey of 50 km wide, legs 0.30 km apart and 4.8 km tall (equating to 16 modeled legs plus the gridded lines), for a total of about 10.4 blocks. This would take about 17.1 days of actual survey effort. Total AIM simulation duration was 16,632 min and shot interval was 8 s.

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. A minimum and maximum value for each of these parameters was specified. These data were extracted from the AIM behavioral database (see sections 2.6.5 and 2.6.6 below), and were used to simulate movements and dive characteristics of individual animats for each species or species group relative to the simulated vessel source tracks at modeling locations.

After the animats were created, they were randomly distributed over each simulation area. The simulation area was delineated by four boundaries, composed of a combination of latitude and

longitude lines. These boundaries extend at least 1 degree of latitude or longitude beyond the extent of the vessel track to insure an adequate number of animats in all directions, and to ensure that the simulation areas extended beyond the area where substantial behavioral reactions might be anticipated. Each simulation had approximately 4,000 animats representing each species. In most cases, this represents a higher density of animats in the simulation (0.1 animats/km²) than occurs in the real environment. This “over-population” allowed the calculation of smoother statistical 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. Thus, the simulations modeled the animals as a closed population with a high residency factor. This approach should be considered moderately conservative in terms of allowing for more prolonged exposures than would be expected from species with a lower residency factor.

Tables A-14 through A-18 provide the number of surveys, by blocks surveyed, for each of the nine modeled regions, both historically (i.e., for years 2004 – 2009) and by projected estimation of the anticipated level of effort (e.g., for 2010 – 2014), for each of the survey types. For OBS surveys in Table A-14, “Light” was not specifically defined, so it was assumed that 50 blocks were surveyed if “light” was specified.

Table A-14. Number of OBS Surveys in each Modeled Region, by Year and Number of Blocks (? = Information not available to BOEM or NMFS).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Year:									
2004	?	?	?	?	?	?	?	?	?
2005	?	?	?	?	?	?	?	?	?
2006	?	?	?	?	?	?	?	?	?
2007	?	?	?	?	?	?	?	?	?
2008	?	?	?	?	?	?	?	?	?
2009	?	?	?	?	?	?	?	?	?
2010	0	light	light	0	light	0	0	light	0
2011	0	light	light	0	light	0	0	light	0
2012	0	light	light	0	light	0	0	light	0
2013	0	light	light	0	light	0	0	light	0
2014	0	light	light	0	light	0	0	light	0

Table A-15. Number of 2-D Surveys in each Modeled Region, by Year and Number of Blocks.

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Year:									
2004	0.0	17377.3	16155.0	0.0	16455.0	15927.2	0.0	66323.8	31854.4
2005	2778.0	9700.8	8522.9	11112.0	7639.5	7408.0	13890.0	74424.5	44448.0
2006	5556.0	1694.6	92.6	2778.0	3039.1	0.0	11871.3	32635.9	803.8
2007	0.0	0.0	0.0	4257.7	0.0	0.0	21288.7	17651.4	64.8
2008	11608.3	1503.8	0.0	4291.1	1722.4	166.7	7496.9	12945.5	1000.1
2009	0.0	138.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	1852.0	926.0	0.0	1852.0	926.0	0.0	1852.0	1852.0	926.0
2011	1852.0	926.0	0.0	1852.0	926.0	0.0	2778.0	5556.0	926.0
2012	3704.0	926.0	926.0	3704.0	926.0	926.0	5556.0	9260.0	926.0
2013	3704.0	1852.0	1852.0	5556.0	1852.0	1852.0	9260.0	16668.0	3704.0
2014	3704.0	1852.0	2778.0	5556.0	1852.0	2778.0	9260.0	16668.0	5556.0

Table A-16. Number of 3-D Surveys in each Modeled Region, by Year and Number of Blocks.

GOMEX model Region: Depth Zone: BOEM Planing Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Year:									
2004	0	723	673	0	11	0	0	1490	181
2005	0	865	173	0	146	0	0	1022	73
2006	0	628	156	0	130	0	0	1836	116
2007	0	565	747	0	63	0	0	762	222
2008	0	223	113	158	0	0	158	316	0
2009	0	352	0	0	0	0	239	786	0
2010	750	400	200	800	50	20	800	400	400
2011	750	300	200	900	50	20	900	500	400
2012	900	300	100	1000	50	0	1000	500	300
2013	1000	300	50	1300	50	0	1300	600	200
2014	1000	300	50	1600	50	0	1600	800	200

Table A-17. Number of WAZ Surveys in each Modeled Region, by Year and Number of Blocks.

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1 Shelf E	2 Shelf C	3 Shelf W	4 Slope E	5 Slope C	6 Slope W	7 Deep E	8 Deep C	9 Deep W
Year:									
2004	0	0	0	0	0	0	0	0	0
2005	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	2530	0
2007	0	105	20	0	828	288	0	2382	365
2008	0	141	0	0	658	128	0	2049	160
2009	0	0	368	0	0	147	0	864	974
2010	0	200	200	0	500	400	0	778	1000
2011	0	200	200	0	450	400	0	700	1600
2012	0	200	200	0	405	400	0	630	2000
2013	0	125	200	500	365	400	0	567	1000
2014	0	100	200	500	328	400	500	510	1000

Table A-18. Number of 2-D High Resolution Surveys in each Modeled Region, by Year and Number of Blocks (? = Information not available to BOEM or NMFS).

GOMEX Model Region: Depth Zone: BOEM Planning Region:	1	2	3	4	5	6	7	8	9
	Shelf	Shelf	Shelf	Slope	Slope	Slope	Deep	Deep	Deep
	E	C	W	E	C	W	E	C	W
Year:									
2004	?	?	?	?	?	?	?	?	?
2005	?	?	?	?	?	?	?	?	?
2006	?	?	?	?	?	?	?	?	?
2007	0	79.5	79.5	0	0	0	0	0	0
2008	0	65	65	0	0	0	0	0	0
2009	0	107.5	107.5	0	0	0	0	0	0
2010	0	122	122	0	0	0	0	0	0
2011	0	30	30	0	0	0	0	0	0
2012	0	35	35	0	0	0	0	0	0
2013	0	35	35	0	0	0	0	0	0
2014	0	35	35	0	0	0	0	0	0

2.6.3 Data Convolution to Create Animal Exposure Histories

The AIM simulations created a realistic animal movement track for each animal and were based on the best available animal behavioral data. It was assumed that, collectively, the ~4,000 animal tracks derived for each simulation (area/species combination) were a reasonable representation of the movements of the animals in the population under consideration. Animal positions along each of these tracks were converted to polar coordinates (range and bearing) from the source to the receivers. These data, along with the depth of the receiver, were used to extract RL estimates from the acoustic propagation modeling results provided by CASS/GRAB. For each bearing, distance, and depth from the source when it was operating at that site, the RL values were expressed as SPLs with units of dB re 1 μ Pa. These SPL values were computed separately for low-frequency (LF), mid-frequency (MF), and high-frequency (HF) cetaceans based on the M-weighting functions described by Southall et al. (2007) so that M-weighting could be applied if desired. M-weighting is a filter function (most akin to human C-weighting) that is applied to the acoustic signal to account for the differential hearing capabilities of different species groups. The final result was a time-history of acoustic exposures for each individual animal every 15 or 30 seconds.

Each animal's received levels were converted from SPL to intensity (Sound Exposure Level, or SEL) and summed over the duration of the exercise to generate the integrated energy level. These were expressed in terms of dB re $1\mu\text{Pa}^2\text{-sec}$ or dB SEL.

2.6.4 Application of Exposure Criteria

Both the Southall et al. (2007) criteria and the traditional 160/180 dB re 1 μ Pa RMS criteria were applied to the results of the AIM modeling, but M-weighting is only applied to the MMPA Level A criteria proposed by Southall et al. (2007). See Table A-19 below.

2.6.5 AIM Animal Movement and Diving Pattern Details

2.6.5.1 *Movement*

Animals move through four dimensions: three-dimensional space, plus time. Several movement parameters are used in AIM to produce a simulated movement pattern that accurately represents real animal movements. A typical dive pattern is shown below in Figure A-34. It consists of two phases; the first is a shallow respiratory sequence, which is followed by a deeper, longer dive.

These two phases are represented in the model with the values as input into the box below in Figure A-35.

The top row has the values for the shallow, respiratory dives. In this case, the animal dives from the surface to a maximum depth of five meters. The second row describes the second phase of the dive. In this phase the animal dives to a depth between 50 and 75 m. In this example, the animal spends time at both 60 and 50 m before surfacing. The pattern then repeats.

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, but larger values would be used for foraging animals or animals that are remaining in the same general area for any number of reasons.

2.6.5.2 *Heading Variance*

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.

2.6.5.3 *Aversions*

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. The example below (Figure A-36) constrains the animal to waters between 2,000 and 5,000 m deep. One modification was made for the AIM simulations in the animal's GOMEX habitat. Normally deep-water species were allowed to move into waters as shallow as 100 m.

Table A-19. Thresholds Applied to AIM Simulations.

Cetacean Threshold Criteria	Standard/Traditional Values	Proposed (Southall et al. 2007) Values
Level A SPL	180 dB re 1 μ Pa	230 dB re 1 μ Pa FLAT (peak)
Level A SEL	N/A	198 dB re 1 μ Pa ² -s (M-weighted)
Level B SPL	160 dB re 1 μ Pa	Use Standard/Traditional Value
Level B SEL	N/A	Use Standard/Traditional Value

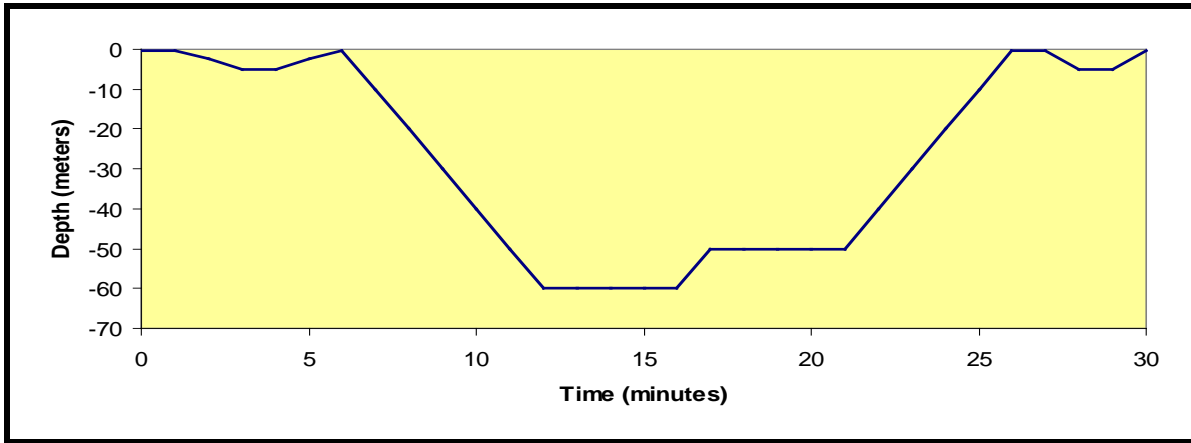


Figure A-34. Typical Animal Dive Pattern.

Physics	Movement	Aversions/Attractions	Acoustics	Representation			
Top Depth (meters)	Bottom Depth (met...	Least Time (Minutes)	Greatest Time (Min...	Heading Variance (...)	Bottom Speed (Km/...	Top Speed (Km/hr)	
0	-5	5	8	20	15	25	
-50	-75	10	15	10	15	25	

Initial Heading : 160 ▼

Figure A-35. Parameters Used to Specify the Dive Behavior for Figure A-34.

Physics		Movement		Aversions/Attractions		Acoustics		Representation			
Data Type	< or >	Value	Units	AND / OR	< or >	Value	Units	Reaction A...	Delta Value	Delta Seco..	Animats/K...
Sound Re...	Greater T...	150.0	dB	And	Ignore	0.0	dB	180.0	0.0	300.0	-1.0
Sea Depth	Greater T...	-2000.0	meters	Or	Less Than	-5000.0	meters	20.0	10.0	0.0	6.0E-4

Figure A-36. Example Showing Aversions to Limit an Animat to Waters Between 2,000 and 5,000 m Deep.

2.6.6 Animal 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 and, as such, 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.

2.6.6.1 *Bryde’s Whale*

There is a paucity of data for this species. Since they are similar in size, data for both sei and Bryde’s whales have been pooled to derive parameters. Note that Sei whales are rare in the Gulf of Mexico, but their similarities to Bryde’s whales was used to determine some of their movement parameters.

Model parameters

	Min/Max Surface Time (min)	Surfacing / Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle / time)	Min /Max Speed (km/h)	Speed Distri- bution	Depth Limit / Reaction Angle
Bryde’s Whale	1/1	90/75	20/150	2/11	30	2/20	Norm.	50/ reflect

Surface Time

No direct data available, fin whale values used.

Dive Depth

No direct data available, fin whale values used.

Dive Time

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 seconds and 15 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/h (Brown, 1977). The highest speed reported for a Bryde's whale was 20 km/h (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/h (Silber et al., 1990).

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.

2.6.6.2 Sperm Whale

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Sperm Whale	8/11	90/75	600/1400 (90) 200/600 (10)	18/65	20	0.1 / 10	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% of the surface times falling 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 meters (Watkins et al., 2002). Foraging dives typically begin at depths of 300 meters (Papastavrou et al., 1989). D-tag data from the Gulf of Mexico show that most foraging dives were between the depths of 400 to 800 meters, with occasional dives between 900 and 1000 meters (Jochens et al 2008).

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). AIM can now accommodate these different dive types, at different frequencies of use.

Type of Dive	N	Depth		Time	
		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	74				

Dive Time

Sperm whale dive times average 44.4 minutes in duration and range from 18.2-65.3 minutes (Watkins et al., 2002).

Speed

Sperm whales are typically slow or motionless on the surface. Mean surface speeds of 1.25 km/h were reported by Jaquet et al. (2000) and 3.42 km/h (Whitehead et al., 1989), while heading variance was identified in Jaquet et. al (1999). Their mean dive rate ranges from 5.22 km/h to 10.08 km/h with a mean of 7.32 km/h (Lockyer, 1997). In Norway, horizontal swimming speeds varied between 0.2 and 2.6 m/s (0.72 and 9.36 km/h) (Wahlberg, 2002). Sperm whales in the Atlantic Ocean swam at speeds between 2.6 and 3.5 km/h (Watkins et al., 1999). Based on these data, a minimum speed of 1 km/h, and a maximum speed of 10 km/h was set for sperm whales, specified with a normal distribution, so that mean speeds will be about 5 km/h.

Habitat

Sperm whales are found almost everywhere, but they are usually in water deeper than 480 meters (Davis et al., 1998). However, there have been sightings of animals in shallow water (40-100 m) (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 (Jaquet and Gendron, 2002). Based on these reports, a compromise value of 200 meters will be used as the shallow water limit for sperm whales.

2.6.6.3 Beaked Whales

Data on the behavior of beaked whales are sparse. Therefore, all beaked whale species have been pooled into a single animal.

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Beaked Whales	1/7		1000/1453 (90) 50/200 (10)	12/70	30	3/6	Norm.	253/reflect

Surface Time

Surface times in Arnoux's beaked whales ranged from 1.2-6.8 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, 1999b).

Dive Depth

The minimum and maximum dive depth measured for a beaked whale was 120 and 1,453 meters, respectively (Hooker and Baird, 1999a). *Ziphius* tagged off the Canary Islands had foraging dives between 824 m and 1,267 m, while Blainsville's beaked whales dove to depths between 655 and 975 m (Johnson et al., 2004).

Dive Time

The minimum and maximum dive time measured was 16 and 70.5 minutes, respectively (Hooker and Baird, 1999a). Sowerby's beaked whales had dives between 12 and (at least) 28 minutes in the Gully in Canada (Hooker and Baird, 1999b). Arnoux's beaked whales 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).

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 surfacings (Hooker and Baird, 1999b).

Speed

Dive rates averaged 1 m/s or 3.6 km/h (Hooker and Baird, 1999a). A mean surface speed of 5 km/h 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 meters (Davis et al., 1998). In the Gully in Canada, Sowerby's beaked whales were found in water ranging from 550 to 1,500 m in depth (Hooker and Baird, 1999b). Blainsville's beaked whales (*M. densirostris*) were found in water depths of 136 to 1,319 m 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 m to > 1,800 m off Scotland and the Faroe Islands (Weir 2000) and between 680 and 1,933 meters in the Gulf of Mexico (Davis et al., 1998).

Group Size

Mesoplodon stejnegeri in Alaska had pod sizes between 5 and 15 animals (Loughlin, 1982).

2.6.6.4 Dwarf and Pygmy Sperm Whales (*Kogia* spp.)

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

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
<i>Kogia</i>	1/2		200/1000	5/12	30	0/11	Norm.	117/ reflect

Surface Time

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

Dive Depth

In the Gulf of Mexico, *Kogia* were found in waters less than 1,000 meters, along the upper continental slope (Baumgartner et al., 2001). Therefore, the dive limits of 200-1,000 meters 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 water almost 2,000 m 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/h) with a mean value of 3 knots (5.6 km/h) (Scott et al., 2001).

Habitat

The minimum depth that *Kogia* was found in the Gulf of Mexico was 176 meters (Davis et al., 1998). Off Hawai‘i, they were found in waters between 450 and 3,200 meters depth, with a mean of 1,425 meters (Baird, 2005). *Kogia* in the Philippines were found in waters from 117 to 3,744 meters in depth (Dolar and Perrin, 2003).

Group Size

Group sizes off Hawai‘i ranged between 1 and 6 animals (Baird, 2005).

2.6.6.5 *Blackfish: False Killer Whale, Pygmy Killer Whale, Melon-headed Whale, Pilot 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. As more data become available, these species will be split into separate animals.

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Blackfish	1/1		5/50/ (80) 50/1000	2/12	30	2/22.4	Gamma.	200/ reflect

Surface Time

A rehabilitated long-finned pilot whale in the North Atlantic was equipped with a satellite tag and a time-depth recorder (TDR). The log survivorship plot of dive time from this animal had a curve at about 40 seconds (Mate et al., 2005). The authors did not feel that this qualified as a breakpoint to separate surface and dive behaviour. 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 (Figure A-37). During the day they never dove to more than 16 meters. However, at night, they dove to a maximum depths of 360 and 648 meters (Baird et al., 2002). Rehabilitated long-finned pilot whales dove to 312 meters on Georges Bank, which has a depth of 360 meters, 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).

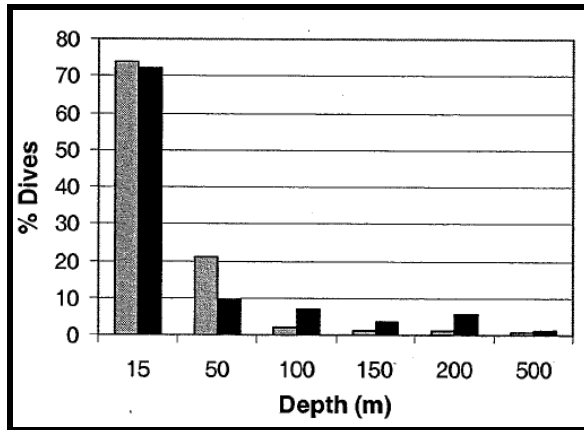


Figure A-37. Long-finned Pilot Whale Dive Depth in the Mediterranean Sea.

Dive Time

Baird et al. (2002) reported on dives of two individuals, and dive times varied between 2.14 and 12.7 minutes during the night. Animals spent all of their time in the top 16 meters during the day.

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 (Figure A-38) (Heide-Jørgensen et al., 2002).

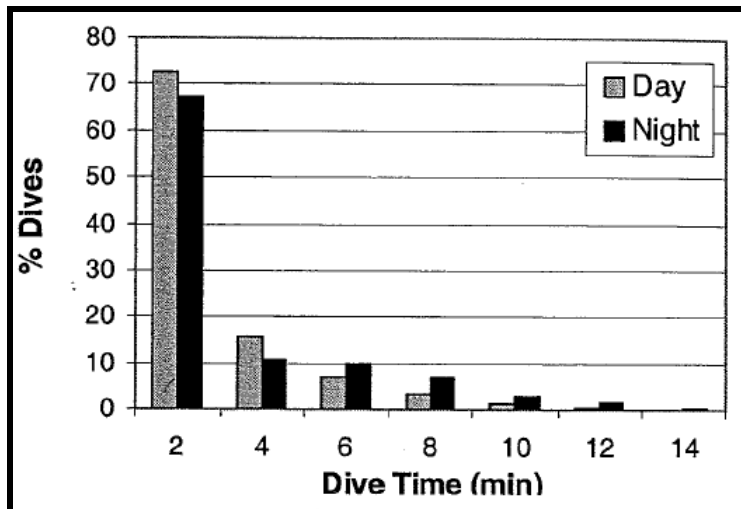


Figure A-38. Long-finned Pilot Whale Dive Times off the Faroe Islands.

Speed

Maximum speed recorded for false killer whales was 8.0 m/s (28.8 km/h) (Rohr et al., 2002), although the typical cruising speed is typically 20-24% less than the maximum speed (Fish and Rohr, 1999). This “typical” maximum of 6.24 m/s (22 km/h) was used as the maximum speed for AIM.

Shane (1995) reported a minimum speed of 2 km/h and a maximum of 12 km/h for pilot whales. It is believed that the Rohr et al. (2002) value is more accurate for maximum speed. During the day in the Mediterranean, animals slowly swam, with mean values for two animals of 0.762 and 0.885 m/s (2.85 and 3.18 km/h), while at night they swam faster, at 1.898 (6.83 km/h) and 1.523 m/s (5.48 km/h) (Baird et al., 2002). A single satellite-tracked long-finned pilot whale had a minimum speed of 1.4 km/h (Mate et al., 2005). The speeds of traveling pilot whales (*G. macrocephalus*) was estimated at 4-5 kts (7.4-9.3 km/h) (Norris and Prescott, 1961) (cited in Mate, 2005). Vertical dive speeds of three TDR tagged animals ranged from 0.79 to 3.38 m/s (2.8 to 12.2 km/h), with a mean of 1.99 m/s (7.2 km/h) (Heide-Jørgensen et al., 2002).

Habitat

The minimum water depth that pilot whales were seen in the Gulf of Mexico was 246 m (Davis et al., 1998) while off of Spain they preferred water deeper than 600 meters (Cañadas et al., 2002).

Group Size

In the Gulf of Mexico, melon-headed whales are found in groups of 35-400 (mean = 135.3, standard error (SE)=36.66, n=10) (Mullin et al., 1994).

2.6.6.6 *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 *Orcinus 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 for “resident” and “transient” killer whales will be developed.

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Killer Whale	1/1		10/180	1/10	30	3/12	Norm.	25/reflect

Dive Depth

Killer whales feeding on herring were observed to dive to 180 meters (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) (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 meters, with a group mean maximum depth of 140.8 meters (SD=61.8, n=34) (Baird et al., 2005). The distribution of dive depths in Baird et al. (2005) was strongly skewed toward shallow values.

Dive Time

Daytime dive times for males was 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 in Baird et al. (2005). Killer whales chasing minke whales had prolonged speeds of 15-30 km/h (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/h, with a mean range of 4.7 to 16.1 km/h (Kriete, 2002). The mean speed of control animals was approximately 5.3 km/h, 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/h without vessels and 6.478 km/h in the presence of vessels (Bain et al., 2005). Taken together, these three studies produced a speed range of 3 to 12 km/h 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.

2.6.6.7 *Risso's Dolphin*

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Risso's Dolphin	1/3		150/1000	2/12	30	2/12	Norm.	150/reflect

Dive Depth

Dive depths of 150 -1000 meters were inferred from its squid-eating habits, and from similar species.

Dive Time

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

Speed

Risso's dolphins off Santa Catalina Island were reported to have speeds that range between 2 and 12 km/h (Shane, 1995).

Habitat

Risso's dolphins were seen in water deeper than 150 meters in the Gulf of Mexico (Davis et al., 1998), but were most often observed in water depths between 300 and 750 meters. Off Chile there were seen in waters deeper than 1,000 meters (Olavarria et al., 2001). Off Spain, they were found to be deep-water species, preferring water deeper than 600 m (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% of the groups contained fewer than 20 animals (Leatherwood et al., 1980).

2.6.6.8 *Bottlenose dolphin*

Bottlenose dolphins in the Gulf of Mexico are found in separate estuarine, coastal, continental shelf and oceanic stocks (Waring et al 2009). The estuarine, coastal and continental shelf animals were modeled with the coastal animal shown below, while the oceanic stock was modeled separately.

Model parameters

	Min/Max Surface Time (min)	Surfacing / 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
Bottlenose (Coastal)	1/1		15/98	1/3	30	2/16	Norm.	10/ reflect
Bottlenose (Pelagic)	1/1		15/200	1/3	30	2/16	Norm.	101/ 1226 reflect

Surface Time

Measured surface times ranged from 38 seconds to 1.2 minutes (Lockyer and Morris, 1986; Lockyer and Morris, 1987; Mate et al., 1995).

Dive Depth

The maximum recorded dive depth for wild bottlenose dolphins is 200 meters (Kooyman and Andersen, 1969). A satellite tagged dolphin, in Tampa Bay, had a maximum dive depth of 98 meters (Mate et al., 1995). This value was used as the maximum dive depth for the coastal form of bottlenose dolphin.

Dive Time

Dive times for a juvenile bottlenose dolphin had a mean value of 55.3 seconds, although the distribution was skewed toward shorter dives (Lockyer and Morris, 1987). This is shown in their figure, reproduced here as Figure A-39.

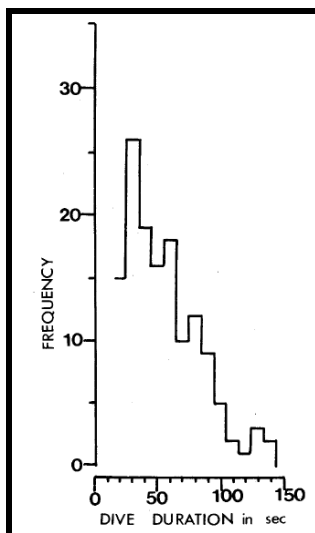


Figure A-39. Bottlenose Dolphin Dive Durations.

Speed

Bottlenose dolphins were observed to swim, for extended periods, at speeds of 4 to 20 km/h, although they could burst (for about 20 seconds) at up to 54 km/h (Lockyer and Morris, 1987). Dolphins in the Sado Estuary, Portugal had a mean speed of 1.2 m/s (4.3 km/h) and maximum speed of 3.2 m/s (11.2 km/h) (Harzen, 2002). A more recent analysis found that maximum speed of wild dolphins was 5.7 m/s (20.5 km/h), 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 (17.3 km/h), with an average speed (relative to water) of 2.2 m/s (7.9 km/h) (Ridou et al. 1997). Bottlenose dolphins off Argentina swam much faster (3.9 m/s, or 14 km/h) when in water > 10 m depth, than in shallow water (1.6 m/s, or 5.8 km/h) (Würsig and Würsig, 1979).

Habitat

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

2.6.6.9 *Stenella: spinner, atlantic/pantropical spotted, and striped dolphins*

Most *Stenella* species have strong diurnal variation in their behavior. This was accounted for 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)	Surfacing / 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
<i>Stenella</i>	1/1		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 meters to feed (Dolar et al., 2003).

Pantropical spotted dolphins off Hawai‘i also dive deeper at night than during the day. The daytime depth had a mean of 12.8 meters, with a maximum of 122 meters, whereas the nighttime mean was 57 meters, with a maximum of 213 meters (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). Most of the time they forage at moderate depths.

Therefore, 10% of the dives will be set to be deep, 40% of the dives will be ‘typical’ foraging depths, with a maximum of 150 meters, and 50% of the dives will represent the daytime resting behaviour, ranging between 5 and 25 meters.

Dive Time

A single spotted dolphin had dive times ranging between 1 and 204 seconds (Leatherwood and Ljungblad, 1979). Pantropical spotted dolphins off Hawai'i had a mean dive duration of 1.95 min (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/h), and were observed to burst to 32 knots (59.3 km/h) (Archer and Perrin, 1999). A speed of 20 km/h 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 (4.3-20 km/h), with bursts exceeding 12 knots (22 km/h) (Leatherwood and Ljungblad, 1979). The estimated burst speed of spotted dolphins in the Eastern Tropical Pacific was 6 m/s (21.6 km/h) for adults and 3 m/s (10.8 km/h) for neonates (newborns). The estimated long-term top speed is 2.5 m/s (9 km/h) for adults and 1 m/s (3.6 km/h) 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/h will be used for long-term movements, as modeled in AIM.

Habitat

In the Gulf of Mexico, spinner dolphins were seen in water deeper than 526 meters, striped dolphins were seen in water deeper than 570 meters and spotted dolphins were seen in water deeper than 102 meters (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 groups were less than 500 animals. The mean of the smaller groups was 101 animals (Archer and Perrin, 1999).

2.6.6.10 *Fraser's dolphin*

Model parameters

	Min/Max Surface Time (min)	Surfacing / Dive Angle	Dive Depth (m) Min/Max (Percentage)	Min/Max Dive Time (min)	Heading Variance (angle / time)	Min /Max Speed (km/h)	Speed Distri-bution	Depth Limit / Reaction Angle
Fraser's Dolphin	1/1		10/700	1/6	30	2/9	Norm.	100/reflect

Dive Depth

Fraser's dolphins dive to about 600-700 meters to feed, 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.

Dive Time

Dive time has been increased to six minutes, to account for the deeper dives.

2.6.6.11 *Rough-toothed 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/h)	Speed distribution	Depth limit / reaction angle
Rough-toothed dolphin	1/3		50/600	3/5	30	5/16	Norm.	194/ reflect

Dive Depth

No dive depth data are available; depths are based upon other species. Since rough-toothed dolphins primarily forage on squid, a deep dive depth is chosen.

Dive Time

The maximum dive time reported for rough-toothed dolphins was 15 minutes (Miyazaki and Perrin, 1994). A more typical range was 0.5 to 3.5 minutes (Ritter 2002).

Speed

Bow-riding rough-toothed dolphins were observed at 16 km/h (Watkins et al., 1987). Porpoising rough-toothed dolphins off the Canary Islands were tracked at >3 knots (5.6 km/h) (Ritter, 2002).

Habitat

Rough-toothed dolphins were seen in water deeper than 194 meters (Davis et al., 1998). Rough-toothed dolphins off the Canary Islands were most often seen in water 100-1,000 m deep, with occasional shallow water sightings, and one group was seen in water 2,500 m deep (Ritter, 2002). Off French Polynesia, animals

were found between 1.8 and 5.5 km offshore, in water between 1,000 and 2,000 meters deep (Gannier and West, 2005).

Group Size

Rough-toothed dolphins off French Polynesia had a mean group size of 10.8 individuals, with a range of 1-35 animals (Gannier and West, 2005).

2.6.7 AIM Results and Adjustments

The output results from AIM found in Tables A-20 and A-21 below provide the number of Level A and Level B harassment takes for each species, by season, modeled region and survey type that exceeded the specific threshold considered. Following the AIM runs, the resulting “ping-histories” or the individual received level values for each of the modeled animals are corrected to account for the correct survey type source level (per Table A-22). This is required because the initial AIM modeling set up assumed the “nominal source” was used. Also, the source level is corrected by the M-weighting correction for that species type. Finally, these results were then corrected to adjust for two parameters in the modeling: 1) the density of animals/animals in the modeled area; and 2) the actual number of blocks that will be surveyed in each modeled region. As discussed previously, the animal densities used in the AIM modeling were deliberately kept high to ensure that a statistically valid result was obtained. Typically, these “modeled” densities are at least an order of magnitude greater than the actual marine mammal density present in the region. Therefore, the modeling result is corrected or scaled by the ratio of the actual density divided by the modeled density. Similarly, the number of potential impacts also is scaled to derive a “per block survey” level of potential impacts. The predicted potential impacts can then be calculated by multiplying this value by the number of surveys of that type to be performed in that year, and summing the potential impacts to that species from all survey types combined.

Table A-20. Estimates of Potential Level A and Level B Harassment Impacts Using AIM and Historic Thresholds.

Marine Mammal Species	Level A (180 dB)						Level B (160 dB)					
	2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
<i>Mysticetes</i>												
Bryde's whale	2.1	1.9	2.0	2.1	0.03	0.03	60.4	42.0	12.8	21.7	118.1	100.1
<i>Odontocetes</i>												
Atlantic spotted dolphin	6647.8	1984.1	282.9	1007.0	9841.7	8034.4	126106.7	35502.2	4394.8	17996.7	182775.1	149084.9
Beaked whales:	77.5	66.7	16.3	29.8	159.1	132.1	1870.5	1434.4	443.0	751.2	3745.4	3184.4
Cuvier's												
Blaineville's												
Gervias'												
Bottlenose dolphin	27925.6	11629.0	1787.0	6229.0	58691.6	47999.2	265774.6	118531.9	26384.7	63431.7	460514.0	379802.9
Clymene dolphin	3109.1	2541.3	771.7	1273.6	6190.4	5257.8	24927.4	17229.8	4301.4	8025.3	49496.3	41423.1
False Killer whale	215.3	176.1	46.5	82.4	442.6	372.3	2635.2	2043.2	676.6	1084.1	5117.4	4383.0
Fraser's dolphin	162.7	130.3	40.4	65.4	323.1	274.5	1460.3	1019.0	308.4	524.7	2831.6	2401.1
Killer whale	820.3	322.1	78.4	167.5	1119.8	928.2	21418.8	7891.6	1628.0	3944.1	29273.6	24126.7
Kogia spp.	266.0	271.6	77.1	124.7	532.3	453.8	1336.3	1280.3	502.9	728.0	2399.1	2119.6
Dwarf sperm whale												
Pygmy sperm whale												
Melonheaded whale	754.8	614.1	158.1	283.4	1555.4	1306.1	8849.5	6811.8	2252.7	3613.8	17122.8	14659.7
Pantropical spotted dolphin	25073.7	18969.7	5523.1	9816.7	51802.1	43606.2	215647.6	148395.2	39765.9	76291.2	441142.2	367083.6
Pygmy killer whale	85.5	72.7	19.7	34.0	176.9	148.9	990.7	762.4	250.7	400.7	1922.9	1649.1
Risso's dolphin	1280.0	828.0	190.8	404.8	2716.9	2246.6	9687.2	6199.2	1853.9	3432.2	19862.9	16684.0
Rough-toothed dolphin	987.8	655.6	129.1	290.1	2030.8	1681.9	9840.8	7226.6	1970.8	3431.7	18032.3	15251.0
Short-finned pilot whale	442.7	372.3	101.3	173.7	900.9	760.0	6115.1	4689.3	1530.4	2469.7	11921.1	10201.7
Sperm whale	217.1	167.7	52.0	90.3	442.6	372.3	2377.2	1833.5	605.6	979.6	4684.7	4015.7
Spinner dolphin	4643.3	3273.3	1202.6	1975.6	8762.5	7466.9	68655.0	34767.6	8648.8	19246.0	139045.2	115052.4
Striped dolphin	5458.3	1924.1	683.2	1100.1	4122.8	3550.9	19240.6	12572.3	3592.8	6600.5	38143.7	31999.1

Table A-21. Estimates of Potential Level A and Level B Harassment Impacts Using AIM and Historic Thresholds with Southall et al. (2007) Applied.

Marine Mammal Species	Level A (SPL-230, SEL-215 dB)						Level B (160 dB)					
	2012	2013	2014	2015	2016	2017	2012	2013	2014	2015	2016	2017
<i>Mysticetes</i>												
Bryde's whale	0.02	0.03	0.03	0.03	0.03	0.03	60.4	42.0	12.8	21.7	118.1	100.1
<i>Odontocetes</i>												
Atlantic spotted dolphin	69.6	49.3	19.1	23.2	123.4	100.9	126106.7	35502.2	4394.8	17996.7	182775.1	149084.9
Beaked whales:	0.1	0.1	0.1	0.1	0.1	0.1	1870.5	1434.4	443.0	751.2	3745.4	3184.4
Cuvier's												
Blaineville's												
Gervias'												
Bottlenose dolphin	1010.2	426.2	65.9	234.8	2182.5	1785.8	265774.6	118531.9	26384.7	63431.7	460514.0	379802.9
Clymene dolphin	278.1	224.6	67.3	109.0	539.2	460.8	24927.4	17229.8	4301.4	8025.3	49496.3	41423.1
False Killer whale	3.2	2.6	3.0	3.0	2.5	3.4	2635.2	2043.2	676.6	1084.1	5117.4	4383.0
Fraser's dolphin	2.9	2.7	2.9	3.1	2.8	3.6	1460.3	1019.0	308.4	524.7	2831.6	2401.1
Killer whale	32.0	11.5	1.0	4.6	45.7	37.4	21418.8	7891.6	1628.0	3944.1	29273.6	24126.7
Kogia spp.	0.8	0.5	0.7	0.6	0.4	0.7	1336.3	1280.3	502.9	728.0	2399.1	2119.6
Dwarf sperm whale												
Pygmy sperm whale												
Melonheaded whale	12.6	17.2	12.3	12.8	10.8	13.1	8849.5	6811.8	2252.7	3613.8	17122.8	14659.7
Pantropical spotted dolphin	1045.9	864.7	365.0	520.2	1835.1	1609.2	215647.6	148395.2	39765.9	76291.2	441142.2	367083.6
Pygmy killer whale	1.0	0.7	0.9	0.8	0.6	0.9	990.7	762.4	250.7	400.7	1922.9	1649.1
Risso's dolphin	1.7	1.6	1.7	1.5	1.4	1.6	9687.2	6199.2	1853.9	3432.2	19862.9	16684.0
Rough-toothed dolphin	1.9	2.0	1.5	1.7	1.6	1.4	9840.8	7226.6	1970.8	3431.7	18032.3	15251.0
Short-finned pilot whale	7.6	9.3	7.4	7.4	6.1	8.3	6115.1	4689.3	1530.4	2469.7	11921.1	10201.7
Sperm whale	19.1	13.9	3.6	6.8	40.7	33.8	2377.2	1833.5	605.6	979.6	4684.7	4015.7
Spinner dolphin	394.1	256.1	69.7	132.8	782.0	650.5	68655.0	34767.6	8648.8	19246.0	139045.2	115052.4
Striped dolphin	189.4	162.4	53.0	83.6	356.6	305.8	19240.6	12572.3	3592.8	6600.5	38143.7	31999.1

3.0 SUMMARY

This appendix provides the detailed information that went into the analysis of the potential impacts to marine mammals in the Gulf of Mexico from prospective G&G operations during the 2010-2014 timeframe. These results are presented in Chapter 4. The DPEIS of which this appendix will be a part will also support the NMFS G&G rulemaking process; specifically, the DPEIS will serve as the NEPA analysis for G&G operations in the GOMEX.

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Appendix B

Current Seismic Surveys Mitigation Measures in the GOM

OMB Control Number: 1010-0151
OMB Expiration Date: December 31, 2011

**UNITED STATES DEPARTMENT OF THE INTERIOR
MINERALS MANAGEMENT SERVICE (MMS)
GULF OF MEXICO (GOM) OCS REGION**

NTL No. 2007-G02

Effective Date: February 7, 2007

NOTICE TO LESSEES AND OPERATORS (NTL) OF FEDERAL OIL, GAS, AND
SULPHUR LEASES IN THE OUTER CONTINENTAL SHELF,
GULF OF MEXICO OCS REGION

**Implementation of Seismic Survey Mitigation Measures and Protected Species Observer
Program**

This NTL supersedes and replaces NTL No. 2004-G01. It does not introduce any new types of mitigation measures; however, it clarifies how you should implement seismic survey mitigation measures, including ramp-up procedures, the use of a minimum sound source, airgun testing and protected species observation and reporting. The measures contained herein apply to all on-lease surveys you conduct under 30 CFR 250 and all off-lease surveys you conduct under 30 CFR 251.

Background

The use of an airgun or airgun arrays while conducting seismic operations may have an impact on marine wildlife, including marine mammals and sea turtles. Some marine mammals, such as the sperm whale (*Physeter macrocephalus*), and all sea turtles that inhabit the GOM are protected under the Endangered Species Act (ESA). All marine mammals are protected under the Marine Mammal Protection Act (MMPA).

In order to protect marine mammals and sea turtles during seismic operations, the National Marine Fisheries Service (NMFS) requires seismic operators to use ramp-up and visual observation procedures when conducting seismic surveys. Procedures for ramp-up, protected species observer training, visual monitoring and reporting are described in detail in this NTL. These mitigation measures apply to geophysical activities conducted under lease terms, for all seismic survey operations conducted in waters deeper than 200 meters (656 feet) throughout the GOM and, in the GOM waters east of 88.0° W. longitude, for all seismic survey operations conducted regardless of water depth. Performance of these mitigation measures is also a condition of the approval of applications for geophysical permits. You must demonstrate your compliance with these mitigation measures by submitting to MMS certain reports detailed in this NTL.

Definitions

Terms used in this NTL have the following meanings:

1. Airgun means a device that releases compressed air into the water column, creating an acoustical energy pulse with the purpose of penetrating the seafloor.
2. Ramp-up means the gradual increase in emitted sound levels from an airgun array by systematically turning on the full complement of an array's airguns over a period of time.
3. Visual monitoring means the use of trained observers to scan the ocean surface visually for the presence of marine mammals and sea turtles. These observers must have successfully completed a visual observer training program as described below. The area to be scanned visually includes, but is not limited to, the exclusion zone. Visual monitoring of an exclusion zone and adjacent waters is intended to establish and, when visual conditions allow, maintain a zone around the sound source and seismic vessel that is clear of marine mammals and sea turtles, thereby reducing or eliminating the potential for injury.
4. Exclusion zone means the area at and below the sea surface within a radius of 500 meters surrounding the center of an airgun array and the area within the immediate vicinity of the survey vessel. Each survey vessel must maintain its own unique exclusion zone.
5. Whales mean all marine mammals in the GOM except dolphins (see definition below) and manatees. This includes all species of baleen whales (Suborder *Mysticeti*), all species of beaked whales (*Ziphius cavirostris* and *Mesoplodon sp.*), sperm whales (*Physeter macrocephalus*), and pygmy and dwarf sperm whales (*Kogia sp.*). Of the baleen whales, only the Bryde's whale (*Balaenoptera edeni*) is expected to be present in the northern GOM and is considered uncommon. This species has primarily been sighted in water depths less than 200 m in the eastern GOM. Sightings of other baleen whale species are highly unlikely.
6. Dolphins mean all marine mammal species in the Family *Delphinidae*. In the GOM, this includes, among others, killer whales, pilot whales, and all of the "dolphin" species.

Ramp-up Procedures

The intent of ramp-up is to warn marine mammals and sea turtles of pending seismic operations and to allow sufficient 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 the ramp-up procedures described below to allow whales, other marine mammals, and sea turtles to depart the exclusion zone before seismic surveying begins.

Measures to conduct ramp-up procedures during all seismic survey, including airgun testing, operations are as follows:

1. Visually monitor the exclusion zone and adjacent waters for the absence of marine mammals and sea turtles for at least 30 minutes before initiating ramp-up procedures. If none are detected, you may initiate ramp-up procedures. Do not initiate ramp-up procedures at night or when you cannot visually monitor the exclusion zone for marine mammals and sea turtles if your minimum source level drops below 160 dB re 1 μ Pa-m (rms) (see measure 5). Altering the vessel's course to shallower water depths (< 200m in the Central and Western Planning Areas) to circumvent ramp-up requirements of the 200 meter isobath will be considered noncompliant.

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 ceasing seismic operations at any time a whale is detected entering or within the exclusion zone. You may recommence seismic operations and ramp-up of airguns only when the exclusion zone has been visually inspected for at least 30 minutes to ensure the absence of marine mammals and sea turtles.
5. You may reduce the source level of the airgun array, using the same shot interval as the seismic survey, to maintain a minimum source level of 160 dB re 1 μ Pa-m (rms) for the duration of certain activities. By maintaining the minimum source level, you will not be required to conduct the 30-minute visual clearance of the exclusion zone 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 30-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.

Protected Species Observer Program

Visual Observers

Visual observers who have completed a protected species observer training program as described below are required on all seismic vessels conducting operations in water depths greater than 200 meters (656 ft) throughout the GOM. Visual observers are required on all seismic vessels conducting operations in OCS water depths less than 200 meters (656 ft.) in the GOM waters east of 88.0° W. longitude. At least two protected species visual observers will be required on watch aboard seismic vessels 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 must resume as soon as conditions permit. Operators may engage trained third party observers, may utilize crew members after training as observers, or may use a combination of both third party and crew observers. During these observations, the following guidelines shall be followed: (1) other than brief alerts to bridge personnel of maritime hazards, no additional duties may be assigned to the observer during his/her visual observation watch (if conditions warrant more vigilant look-outs when navigating around or near maritime hazards, additional personnel must be used to ensure that watching for protected species remains the primary focus of the on-watch observers), (2) no observer will be allowed more than 4 consecutive hours on watch as a visual observer, (3) a "break" time of no less than 2 hours must be allowed before an observer begins another visual monitoring watch rotation (break time means no assigned observational duties), and (4) no person (crew or third party) on watch as a visual observer will be assigned a combined watch

schedule of more than 12 hours in a 24-hour period. Due to the concentration and diligence required during visual observation watches, operators who choose to use trained crew members in these positions may select only those crew members who demonstrate willingness as well as ability to perform these duties.

Training

All visual observers must have completed a protected species observer training course. MMS will not sanction particular trainers or training programs. However, basic training criteria have been established and must be adhered to by any entity that offers observer training. Operators may utilize observers trained by third parties, may send crew for training conducted by third parties, or may develop their own training program. All training programs offering to fulfill the observer training requirement must: (1) furnish to MMS, at the address listed in this NTL, 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 MMS 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 GOM,
- II. Brief overview of seismic acquisition operations in the GOM,
- III. Overview of seismic mitigation measures (NTLs) and the protected species observer program in the GOM,
- IV. Discussion of the role and responsibilities of the protected species observer in the GOM, including:
 - a) Legal requirements (why you are here and what you do),
 - b) Professional behavior (code of conduct),
 - c) Integrity,
 - d) Authority of protected species observer to call for shut-down of seismic acquisition operations,
 - e) Assigned duties,
 - 1) What can be asked of the observer,
 - 2) What cannot be asked of the observer,
 - f) Reporting of violations and coercion,
- V. Identification of GOM marine mammals and sea turtles, with emphasis on whales,
- VI. Cues and search methods for locating marine mammals, especially whales, and sea turtles,
- VII. Data collection and reporting requirements:
 - a) Forms and reports to MMS via email at protectedspecies@mms.gov on the 1st and 15th of each month,
 - b) Whale in exclusion zone/shut-down report within 24 hours.

Visual Monitoring Methods

The observers on duty will look for whales, other marine mammals, and sea turtles using the naked eye and 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° coverage surrounding the seismic vessel and will adjust their positions appropriately to ensure adequate coverage of the entire area. These observations must be consistent, diligent, and free of distractions for the duration of the watch.

Visual monitoring will begin no less than 30 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 a marine mammal or sea turtle is observed, the observer should note and monitor the position (including lat./long. of vessel and relative bearing and estimated distance to the animal) until the animal dives or moves out of visual range of the observer. Make sure you continue to observe 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 whale is observed within an estimated 500 meters (1,640 feet) of the sound source array (“exclusion zone”), whether due to the whale’s movement, the vessel’s movement, or because the whale surfaced inside the exclusion zone, the observer will call for the immediate shut-down of the seismic operation, including airgun firing (the vessel may continue on its course but all airgun discharges must cease). The vessel operator must comply immediately with such a call by an on-watch visual observer. Any disagreement or discussion should occur only after shut-down. When no marine mammals or sea turtles are sighted for at least a 30-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 30 minutes prior to commencement of ramp-up (unless the method described in the section entitled “Experimental Passive Acoustic Monitoring” is used). Thus, ramp-up cannot begin after dark or in conditions that prohibit visual inspection (fog, rain, etc.) of the exclusion zone. Any shut-down due to a whale(s) sighting within the exclusion zone must be followed by a 30-minute all-clear period and then a standard, full ramp-up. Any shut-down 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 whales, other marine mammals, or sea turtles are observed in the exclusion zone. If whales, other marine mammals, or sea turtles are observed in the exclusion zone during the short silent period, resumption of seismic survey operations must be preceded by ramp-up.

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 MMS, and subsequently NOAA Fisheries, determine the need for and effectiveness of mitigation measures. Information on observer effort and seismic operations are 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 the MMS:

Observer Effort Report: Prepared for each day during which seismic acquisition operations are conducted. Furnish an observer effort report to MMS on the 1st and the 15th of each month that includes:

- Vessel name,
- Observers' names and affiliations,
- Survey type (e.g., site, 3D, 4D),
- MMS Permit Number (for "off-lease seismic surveys") or OCS Lease Number (for "on-lease seismic surveys"),
- Date,
- Time and lat./long. when daily visual survey began,
- Time and lat./long. when daily visual survey ended,
- Average environmental conditions while on visual survey, including
 - Wind speed and direction,
 - Sea state (glassy, slight, choppy, rough or Beaufort scale),
 - Swell (low, medium, high or swell height in meters),
 - Overall visibility (poor, moderate, good).

Survey Report: Prepared for each day during which seismic acquisition operations are conducted and the airguns are being discharged. Furnish a survey report to MMS on the 1st and the 15th of each month during which operations are being conducted that includes:

- Vessel name,
- Survey type (e.g., site, 3D, 4D),
- MMS Permit Number (for "off-lease seismic surveys") or OCS Lease Number (for "on-lease seismic surveys"),
- Date,
- Time pre-ramp-up survey begins,
- What marine mammals and sea turtles were seen during pre-ramp-up survey?

- Time ramp-up begins,
- Were whales seen during ramp-up?
- Time airgun array is operating at the desired intensity,
- What marine mammals and sea turtles were seen during survey?
- If whales were seen, was any action taken (i.e., survey delayed, guns shut down)?
- Reason that whales might not have been seen (e.g., swell, glare, fog),
- Time airgun array stops firing.

Sighting Report: Prepared for each sighting of a marine mammal (whale or dolphin) or sea turtle made during seismic acquisition operations. Furnish a sighting report to MMS on the 1st and the 15th of each month during which operations are being conducted that includes:

- Vessel name,
- Survey type (e.g., site, 3D, 4D),

- MMS Permit Number (for “off-lease seismic surveys”) or OCS Lease Number (for “on-lease seismic surveys”),
- Date,
- Time,
- Watch status (Were you on watch or was this sighting made opportunistically by you or someone else?),
- Observer or person who made the sighting,
- Lat./long. of vessel,
- Bearing of vessel,
- Bearing and estimated range to animal(s) at first sighting,
- Water depth (meters),
- Species (or identification to lowest possible taxonomic level),
- Certainty of identification (sure, most likely, best guess),
- Total number of animals,
- Number of juveniles,
- 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),
- Direction of animal’s travel – compass direction,
- Direction of animal’s travel – related to the vessel (drawing preferably),
- Behavior (as explicit and detailed as possible; note any observed changes in behavior,)
- Activity of vessel,
- Airguns firing? (yes or no),
- Closest distance (meters) to animals from center of airgun or airgun array (whether firing or not).

Note: If this sighting was of a whale(s) within the exclusion zone that resulted in a shut-down of the airguns, include in the sighting report the observed behavior of the whale(s) before shut-down,

the observed behavior following shut-down (specifically noting any change in behavior), and the length of time between shut-down and subsequent ramp-up to resume the seismic survey (note if seismic survey was not resumed as soon as possible following shut-down). Send this report to MMS **within 24 hours of the shut-down**. 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 MMS on the 1st and the 15th of each month (with one exception noted above). Forms should be scanned (or data typed) and sent via email to protectedspecies@mms.gov. Please note that these marine mammal and sea turtle reports are in addition to any reports you submit under NTL No. 98-20, dated September 15, 1998, and NTL No. 2005-G07, effective July 1, 2005, and all progress and final reports required as a condition of your geophysical permit.

Borehole Seismic Surveys

Borehole seismic surveys differ from surface seismic surveys in a number of ways, including the use of much smaller airgun arrays, having an average survey time of 12-24 hours, utilizing a

sound source that is not usually moving at 4-5 knots, and requiring the capability of moving the receiver in the borehole between shots. Due to these differences, the following altered mitigations apply only to borehole seismic surveys:

- During daylight hours, when visual observations of the exclusion zone are being performed as required in this NTL, borehole seismic operations will not be required to ramp-up for shutdowns of 30 minutes or less in duration, as long as no whales, other marine mammals, or sea turtles are observed in the exclusion zone during the shutdown. If a whale, other marine mammal, or sea turtle is sighted in the exclusion zone, ramp-up is required and may begin only after visual surveys confirm that the exclusion zone has been clear for 30 minutes.
- During nighttime or when conditions prohibit visual observation of the exclusion zone, ramp-up will not be required for shutdowns of 20 minutes or less in duration. For borehole seismic surveys that utilize passive acoustics during nighttime and periods of poor visibility, ramp-up is not required for shutdowns of 30 minutes or less.
- Nighttime or poor visibility ramp-up is allowed only when passive acoustics are used to ensure that no whales are present in the exclusion zone (as for all other seismic surveys). Operators are strongly encouraged to acquire the survey in daylight hours when possible.
- Protected species observers must be used during daylight hours, as required in this NTL, and may be stationed either on the source boat or on the associated drilling rig or platform if a clear view of the sea surface in the exclusion zone and adjacent waters is available.
- All other mitigations and provisions for seismic surveys as set forth in this NTL will apply to borehole seismic surveys.
- Reports should reference OCS Lease Number, Area/Block and Borehole Number.

Experimental Passive Acoustic Monitoring

Whales, especially sperm whales, are very vocal marine mammals, and 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, sperm whales are at the greatest risk of potential injury from seismic airguns when they are submerged and under the airgun array. Passive acoustic monitoring appears 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. MMS strongly encourages operators to participate in an experimental program by including passive acoustic monitoring as part of the protected species observer program. Inclusion of passive acoustic monitoring does **not** relieve an operator of any of the mitigations (including visual observations) in this NTL **with the following exception**: Monitoring for whales 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. If you use passive acoustic monitoring, include an assessment of the usefulness, effectiveness, and problems encountered with the use of that method of marine mammal detection in the reports described in this NTL. A description of the passive acoustic system, the software used, and the monitoring plan should also be reported to MMS at the beginning of its use.

Paperwork Reduction Act

The PRA (44 U.S.C. Chapter 35) requires us to inform you that we collect the information described in this NTL to ensure that you conduct operations in a manner that will not jeopardize threatened or endangered species or destroy or adversely modify critical habitat that has been designated for those species. We protect all proprietary information submitted according to the Freedom of Information Act and 30 CFR 250.196. An agency may not conduct or sponsor a collection of information unless it displays a currently valid Office of Management and Budget (OMB) control number. You are not obligated to respond until the OMB has approved this collection of information. We estimate the total hour burden to be 751 hours and the total "non-hour cost" burden to be \$1,854,080. Direct comments regarding the burden, or any other aspect of this information collection, to the Information Collection Clearance Officer, Mail Stop 5438, Minerals Management Service, 1849 C Street, NW, Washington, DC 20240. In addition, this NTL refers to information collection requirements under 30 CFR 250, subpart B. The OMB has approved all of the information collection requirements in these regulations and assigned OMB Control Number 1010-0151.

Contact

Any questions regarding this NTL should be submitted in writing to: protectedspecies@mms.gov.

Submittals by mail may be directed to:

Minerals Management Service Gulf of Mexico OCS Region Attention: Environmental Sciences Unit
(MS 5430) 1201 Elmwood Park Blvd. New Orleans, LA 70123-2394

[original signed by]

Chris C. Oynes Regional Director

APPENDIX C

Methodology for recalculation of new take estimates for the period 2012-2017

- 1) Calculations for all 5 activity types were completed for the period 2012-2017 so that we would have information in the event that the rule is completed in 2012. So there are estimates for 6 years, instead of 5.
- 2) For each activity new projected estimates were provided by industry. These data were used for all calculations for the years 2012-2017. Industry only provided estimates for activity by planning area (Eastern, Central, and Western) and did not break the activity down any further into shelf, slope, and deep.
- 3) In order to further subdivide the projected activity amounts into shelf, slope and deep, tables E14-18 (Appendix E) were used to calculate proportions for each of the 9 modeled regions. Proportional values for 2012-2014 were used in the new calculations and the values for 2014 were maintained for years 2015-2017. This is appropriate considering BOEMRE's 5-year planning cycle for the GOM which covers the years 2012-2107.
 - a. For example: If in 2012, 1/3 (.333) of all projected 2D activity in the Eastern Planning area was in shelf waters, that proportion was used for calculations with the new projected values.
- 4) For each activity (OBS, 2D high resolution, 2D, 3D, and WAZ) two excel spreadsheets were created with the following worksheets for both standard thresholds (180/160 dB) and Southhall (230/160 dB):
 - a. "*Original Activity from MAP*" (the values highlighted in yellow were used to determine proportions)
 - b. "*New Activity from Industry*" (the values highlighted in pink were used in the calculations)
 - c. "*My Calculations*" (these contain calculations to determine proportions, number of blocks, and total values highlighted in yellow by water depth and planning area. The value for 2012-2017 was used in the take calculations)
 - d. "*MAI Table E-xx*" this identifies the Table used from Appendix E that provides the Level A and B take estimates by block for each species. For all calculations tables using AIM methodology and Southhall (2007) thresholds were used (Tables E37-41).
 - e. "*New Take Estimates*" Totals for 6-year period for the activity are summed across planning areas and water depths and a total is highlighted in yellow. These values will be what is included in a summary table for the petition
 - f. "*Take Estimates by Year*" This sheet sums the calculations from the separate worksheets (2012, 2013, 2014, 2015, 2016, 2107)

- 5) For OBS – the same proportions were used for the new industry calculations because industry data did not delineate OBS separately from 3D. OBS is only projected for 4 modeled regions (2,3,5,8) and was kept at the same level of activity which was previously considered “light” or 50 blocks.
- 6) While 2D and 3D high resolution surveys were not previously separated in terms of activity (Table E-18), MAI calculated separate take estimates for each (Tables E41-42). New high resolution survey projections were provided by industry and because the predominant types of high resolution survey in the GOM are 2D, only 2D high-res survey calculations were completed using Tables E-41 and E-35. New industry estimates were in miles. To convert miles to blocks, an estimate of 360 miles of survey miles per block was used (as per R. Brinkman 3/16/2011).
 - a. For example: $581 \text{ miles} * 1/360 = 1.61 \text{ blocks}$

In addition, BOEMRE is implementing new survey requirements for on-lease activities that may require surveys in all planning areas and water depths (either new surveys or re-processing of existing data). So industry projections for high resolution surveys were multiplied by equal proportions for each planning area and water depth (0.333).

- 7) For 2D seismic, industry provided projections in miles. In order to convert miles to blocks, MAI multiplied the number of miles by 1.852 and this was used again for the new calculations.
 - a. For example: $1000 \text{ miles} * 1.852 \text{ blocks/mile} = 1852 \text{ blocks}$
- 8) Calculations for 3D and WAZ were similar to 2D except that industry provided estimates in blocks so no “mile to block” conversion was needed.
- 9) For each category of activity the calculations are essentially the same (minus the conversions from miles to blocks for 2D and 2D high res).
- 10) Take estimate = Total amount of activity for the year * proportion for that depth and planning area * the estimated level of take by species for one block (from Tables E37-41 for 230 dB, Tables E31-35 for 180 dB)

All projected values for each of the 5 activities were summed by year (2012-2017) for both standard thresholds (180/160 dB) and for Southall (230/160 dB). These values are presented in the petition in Tables 6-1 and 6-2.