DEPARTMENT OF THE AIR FORCE
HEADQUARTERS 96TH AIR BASE WING (AFMC)
EGLIN AIR FORCE BASE FLORIDA

Mr. Stephen M. Seiber
Chief, Natural Resources Section
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501 De Leon Street, Suite 101
Eglin AFB FL 32542-5133

MAY 5 2011

Mr. Michael Payne
Office of Protected Resources
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910-3226

Dear Mr. Payne:

This submittal is a formal request from Eglin Air Force Base (AFB) for a one-year Incidental Harassment Authorization (IHA) until a five-year Letter of Authorization (LOA) is issued for air-to surface gunnery activities associated with Air Force Special Operations Command (AFSOC) use of the Eglin Gulf Test and Training Range (EGTTR) at Eglin AFB. This project received an IHA on January 25, 2010 that expired on January 26, 2011 and the Air Force would like to request a renewal. The activities analyzed in this request are the same as those previously analyzed in Eglin's 2003 LOA application; however the number of proposed training events has been reduced to account for actual mission needs. In addition, marine mammal descriptions and densities have been updated and a more recent acoustic analysis was conducted to account for new threshold criteria and updated methodologies.

Eglin Natural Resources Section is requesting take for harassment only, including Level A and Level B (physiological and behavioral) harassment. No Level A mortality takes are anticipated to occur. Mitigation measures are expected to substantially decrease the magnitude of potential impacts.

The NMFS will be notified immediately if any of the actions considered in this proposed action are modified. Any modifications or conditions resulting from consultation or permitting with the NMFS will be implemented prior to commencement of activities. The Natural Resources Section believes this fulfills all requirements for the permitting process to proceed.

If you have any questions regarding this letter or any of the proposed activities, please do not hesitate to contact either Mr. Bob Miller (850-883-1153) or myself at (850) 882-8391.

Sincerely

STEPHEN M. SEIBER, GS-13
Chief, Natural Resources Section

Attachment:
Request for a One-Year Incidental Harassment Authorization and a Five-Year Letter of Authorization for the Incidental Harassment of Marine Mammals Resulting from the Programmatic Mission Activities Within the Eglin Gulf Test and Training Range (EGTTR)

REQUEST FOR A ONE-YEAR INCIDENTAL HARASSMENT AUTHORIZATION AND A FIVE-YEAR LETTER OF AUTHORIZATION FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM THE PROGRAMMATIC MISSION ACTIVITIES WITHIN THE EGLIN GULF TEST AND TRAINING RANGE (EGTTR)

EGLIN AIR FORCE BASE, FLORIDA

Submitted To:

Office of Protected Resources
National Marine Fisheries Service (NMFS)
1315 East-West Highway
Silver Spring, MD 20910-3226

Submitted By:

Department of the Air Force
96 CEG/CEVSN
Natural Resources Branch
501 DeLeon Street, Suite 101
Eglin AFB FL 32542-5133

May 2011

PRINTED ON RECYCLED PAPER

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LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

μsec	Microseconds
ABR	Auditory Brainstem Response
AEP	Auditory Evoked Potential
CT	Computerized Tomography
dB re 1 μPa^2-s	Decibels Referenced To One Squared Micropascal-Second
EFD	Energy Flux Density
EGTTR	Eglin Gulf Test and Training Range
ESA	Endangered Species Act of 1973
LOA	Letter of Authorization
FY	Fiscal Years
ft	feet
GOM	Gulf of Mexico
HE	High Explosive
Hz	Hertz
IDS	Infrared Detection Sets
IHA	Incidental Harassment Authorization
in-lb/in^2	Inch-Pounds Per Square Inch
IR	Infrared Sensors
J/m^2	Joules Per Square Meter
kHz	KiloHertz
km^2	Square Kilometer
kn	knot
m	Meter
mm	Millimeter
MMPA	Marine Mammal Protection Act
m/s	Meters Per Second
NM	Nautical Mile
NM^2	Square Nautical Miles
NMFS	National Marine Fisheries Service
NODE	Navy OPAREA Density Estimates
Pa-s	Pascal-Second
PBR	Potential Biological Removal
PEA	Programmatic Environmental Assessment
psi	Pounds Per Square Inch
psi-msec	Pounds Per Square Inch Per Millisecond
PTS	Permanent Threshold Shift
SST	Sea Surface Temperature
SERO	Southeast Regional Office
SEL	Sound Exposure Level
S-tag	Satellite-Tag
TM	Tympanic-Membrane
TTS	Temporary Threshold Shifts
TV	Television
ZOI	Zone of Influence

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EXECUTIVE SUMMARY

With this submittal, Eglin Air Force Base requests a 5-year Letter of Authorization (LOA) and a 1-year Incidental Harassment Authorization (IHA) for the incidental taking, but not intentional taking (in the form of noise-related harassment), of small numbers of marine mammals incidental to the programmatic mission activities within the Eglin Gulf Test and Training Range (EGTTR), as permitted by the Marine Mammal Protection Act (MMPA) of 1972, as amended. The air-to-surface gunnery test and training activities comprise the majority of Eglin's missions that deploy ordnance into the Gulf of Mexico and have been found to be the only impactive activities in the EGTTR Programmatic Environmental Assessment (PEA). An IHA was issued on January 25, 2010 and expired on January 26, 2011. A new 1-year IHA is being requested to cover air-to-surface gunnery test and training activities until a new 5-year LOA is issued. The activities analyzed in this LOA/IHA request are the same as those previously analyzed in Eglin's 2003 LOA application; however the number of proposed training events and number of rounds expended has been updated. Marine mammal descriptions and densities have also been updated with the best available information. In addition, a more recent acoustic analysis has been conducted to account for new threshold criteria and updated methodologies.

Air-to-surface gunnery missions involve surface impacts of ordnance projectiles and result in small underwater detonations (up to approximately 5 pounds). These activities may expose cetaceans that potentially occur within the EGTTR to noise. Gunnery mission activities, although conducted primarily in the W-151 ranges, may potentially occur anywhere within the EGTTR. All guns are fired at specific targets in the water, usually MK-25 flares. The 105 mm training round will be used during nighttime gunnery training. The potential takes outlined in Section 6 represent the maximum expected number of animals that could be affected. Eglin AFB has employed a number of mitigation measures in an effort to substantially decrease the number of animals potentially affected. Eglin AFB is committed to assessing the mission activity for opportunities to provide operational mitigations (i.e. ramping up and using nighttime training rounds) while potentially sacrificing some mission flexibility.

Using a conservative density estimate for each species, the zone of influence (ZOI) of each type of round deployed, and the total number of events per year, an annual estimate of the potential number of animals exposed to noise was analyzed. Gunnery noise is anticipated to affect some marine mammal species. The total number of marine mammals exposed to Level A mortality noise levels (30.5 psi-msec) is effectively zero (0.01 animals). Therefore no mortality takes are considered. A total of four marine mammals would potentially be exposed to injurious Level A harassment noise levels (205 dB re 1 μPa^2-s or higher). Approximately 212 marine mammals would potentially be exposed (annually) to a non-injurious (TTS) Level B harassment noise level associated with the 182 dB re 1 μPa^2-s threshold and approximately 694 animals would potentially experience (annually) noise at the behavioral threshold (177 dB re 1 μPa^2-s).

Other components of Eglin's programmatic mission activities that could potentially affect marine mammals were considered in Chapter 4 of the EGTTR PEA. These components included supersonic and subsonic noise from aircrafts, occasional fuel releases, debris, the release of chemicals into the water from munitions, chaff, flares, drones, and missiles, and direct physical impacts (strikes) resulting from air-to-surface gunnery activities, inert bomb use, and missile and drone fragments falling into the water. The effects of each were determined to be insignificant. Six strategic marine mammal stocks could potentially be affected, including the sperm whale and five bottlenose dolphin stocks. However, the likelihood of significant impacts to these stocks is considered low due to the typical habitats occupied by the species and to mitigation (monitoring) measures. The sperm whale is listed as threatened under the Endangered Species Act of 1973.

The information and analyses provided in this application are presented to fulfill the LOA requirements in Paragraphs (1) through (11) of 50 Code of Federal Regulations (CFR) 228.4(a).

1. DESCRIPTION OF ACTIVITIES

This section describes the mission activities conducted in the Eglin Gulf Test and Training Range (EGTTR) that could result in takes under the Marine Mammal Protection Act (MMPA) of 1972, as amended. The actions fall under the category of Eglin ordnance testing and training. Air-to-surface gunnery missions, which are categorized as “military readiness” activities, involve surface impacts of projectiles and small underwater detonations (up to approximately 5 pounds) with the potential to affect cetaceans that may potentially occur within the EGTTR. These missions typically involve the use of 25 millimeter (mm), 40 mm, and 105 mm gunnery rounds (Figure 1-1). The Air Force has developed a 105 mm training round that contains less than 10 percent of the amount of explosive material as compared to the 105 Full Up round. The training round was developed as a method to mitigate effects on marine life. In the 2003 Letter of Authorization (LOA) application, baseline activities were derived from levels of activity captured during fiscal years (FY) 95, 96, 97, 98, and 99. This baseline is no longer valid as actual missions conducted over the last 10 years were lower than anticipated. A new baseline has been developed from more accurate estimates provided by user groups based on actual and potential mission frequency.

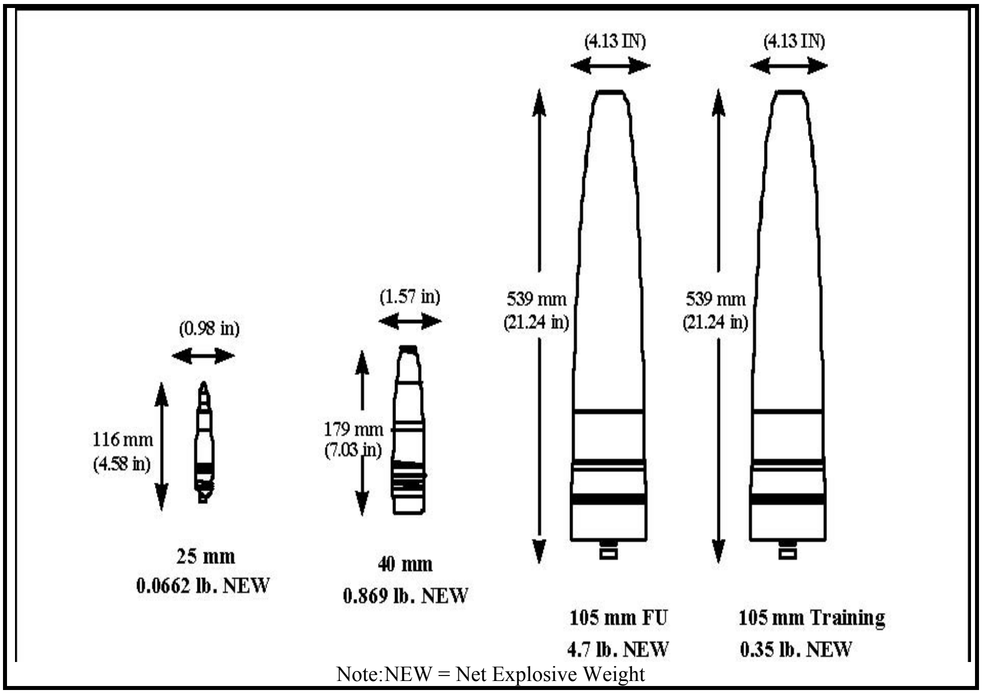

Figure 1-1. Projectiles of the Air-to-Surface Operations in the EGTTR

Other components of Eglin’s programmatic mission activities that could potentially affect marine mammals were considered in Chapter 4 of the EGTTR Programmatic Environmental Assessment (PEA) (U.S. Air Force, 2002). These components included supersonic and subsonic noise from aircraft flight (approximately 39,000 sorties per year), occasional fuel releases, debris, release of chemicals into the water from munitions, chaff, flares, drones, and missiles, and direct physical impacts (strikes) resulting from air-to-surface gunnery operations, inert bomb use, and missile and drone fragments falling into the water. The effects of each of these were determined to be insignificant, and take is not requested for these activities. Please refer to pages 4-1 through 4-33 in the EGTTR PEA for analyses of Eglin's programmatic mission activities other than noise-related air-to-surface gunnery activities. In addition, the National Marine Fisheries Service's (NMFS) Notice of Proposed IHA (74 FR 53474, October 19, 2009) provides a detailed discussion of possible direct physical impact and concludes that such impact is highly unlikely. Therefore, discussion of potential impacts to marine mammals in this document is limited to noise effects associated with air-to-surface gunnery operations.

Air-to-Surface Gunnery Operations

Water ranges within the EGTTR (Figure 1-2) that are typically used for the gunnery operations include W-151A, W-151B, W-151C, and W-151D (Figure 1-3). Based on range utilization data, W-151A is the most frequently used water range due to its proximity to Hurlburt Field. Gunships normally transit from Hurlburt Field to the water ranges at a minimum of 4,000 feet (ft) above surface level. At a typical distance from the coast of at least 15 miles (beyond the 12 nautical mile [NM] territorial sea boundary), the crews scan a 5-NM radius around the potential impact area to ensure it is clear of surface craft, marine species, and other objects that would make the site unsuitable. Scanning is accomplished using radar, all-light television (TV), infrared sensors (IR), and visual means. An alternative area would be selected if any cetaceans or vessels were detected within the 5-NM search area. Once the scan is completed, MK-25 marking flares are dropped onto the water surface as targets, and the firing sequence is initiated.

A typical gunship mission lasts approximately five hours without refueling and six hours when air-to-air refueling is accomplished. A typical mission includes:

- 30 minutes to take off and perform airborne sensor alignment; align electro-optical sensors (IR and TV) to heads-up display.
- 1½ to 2 hours of dry fire (no ordnance expended); this time includes transition time.
- 1½ to 2 hours of live fire; this time includes clearing the area and transiting to and from the range; actual firing activities typically do not exceed 30 minutes.
- 1 hour air-to-air refueling, if included in the mission.
- 30 minutes transition work (takeoffs, approaches, landings, and pattern work).

The guns are fired during the live fire phase of the mission. The actual firing can last from 30 minutes to 1½ hours but is typically completed in 30 minutes. The number and type of air-to-surface gunnery munitions deployed during a mission varies with each type of mission flown. Training rounds for the 105-mm ammunition are used during nighttime training.

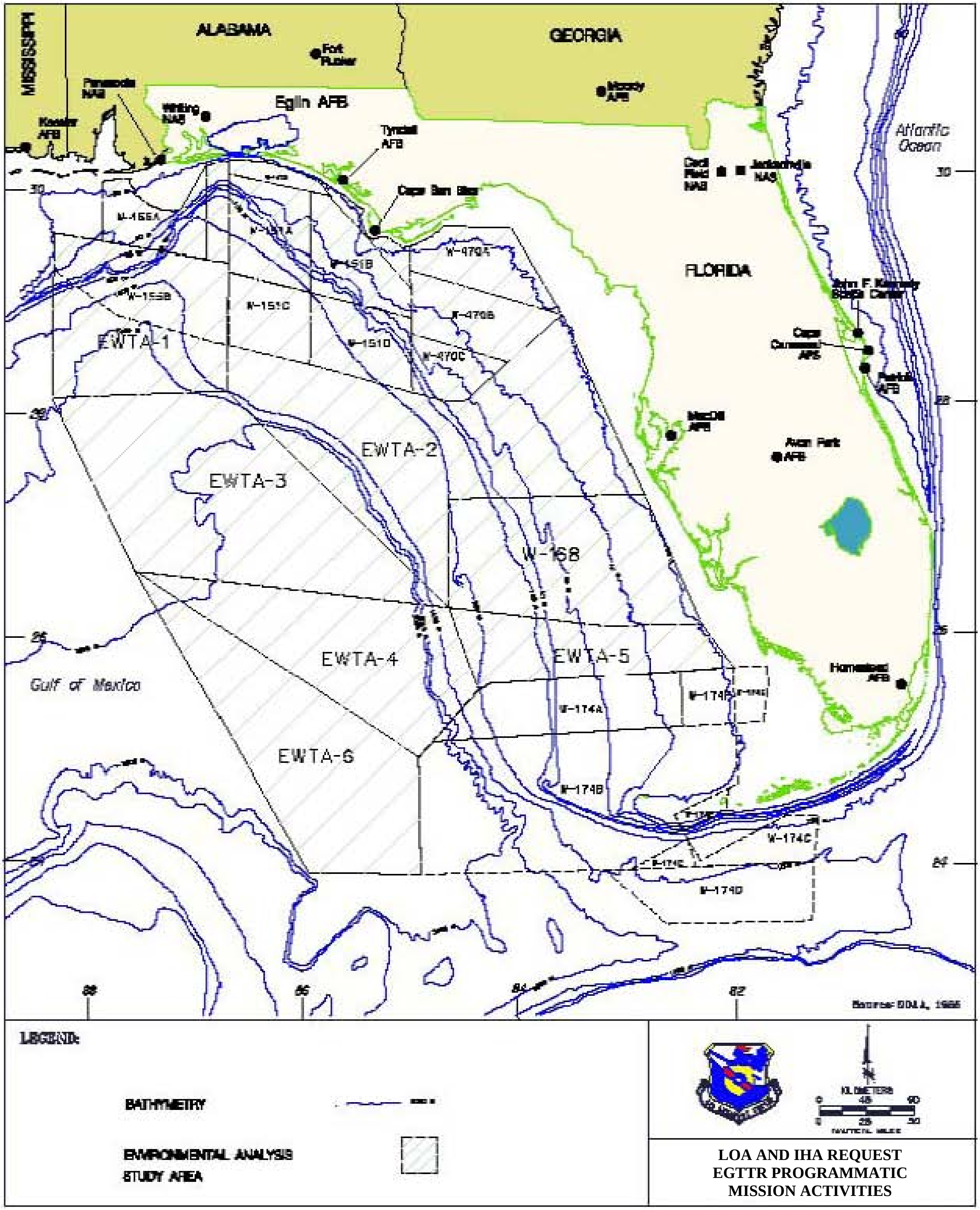

Figure 1-2. Eglin Gulf Test and Training Range

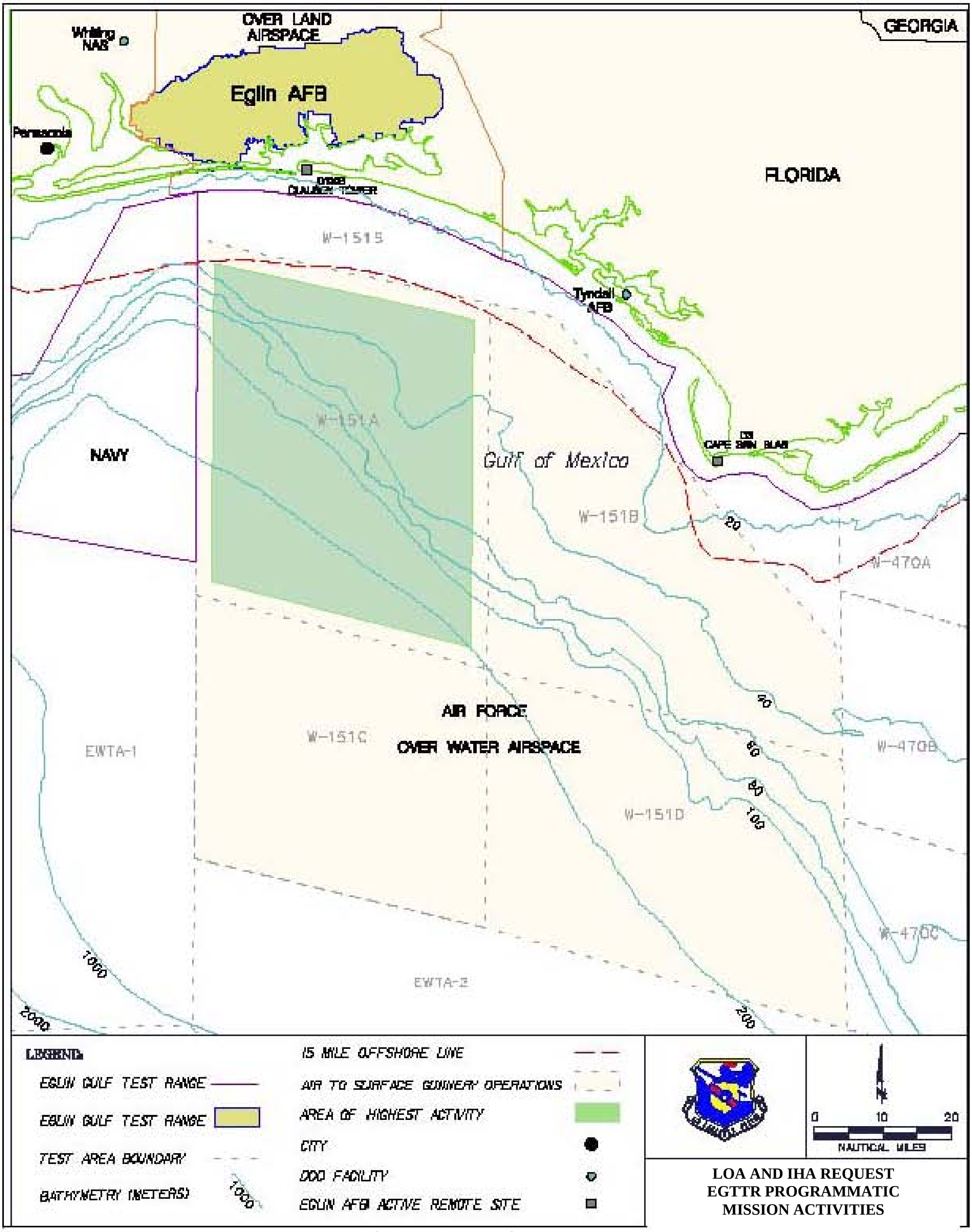

Figure 1-3. Primary Region for Air-to Surface Gunnery Missions in the EGTTR

All guns are fired at a specific target in the water, typically MK-25 flares. Two flares are deployed into the center of the 5-NM cleared area in order to establish the test area. The flare's burn time is generally 10 to 20 minutes, but could be less if actually hit with one of the ordnance projectiles; however, some flares have burned as long as 40 minutes. Live fires are a continuous event with pauses during the firing usually well under a minute and rarely from 2 to 5 minutes. Firing pauses would only exceed 10 minutes if one of the following situations arose: 1) surface boat traffic caused the mission to relocate; 2) aircraft, gun, or targeting system problems existed; or 3) more flares needed to be deployed. The Eglin Safety Office has further described the gunnery missions as having 95 percent containment with a 99 percent confidence level within a 5-meter (m) area around the established flare target test area (Figure 1-4).

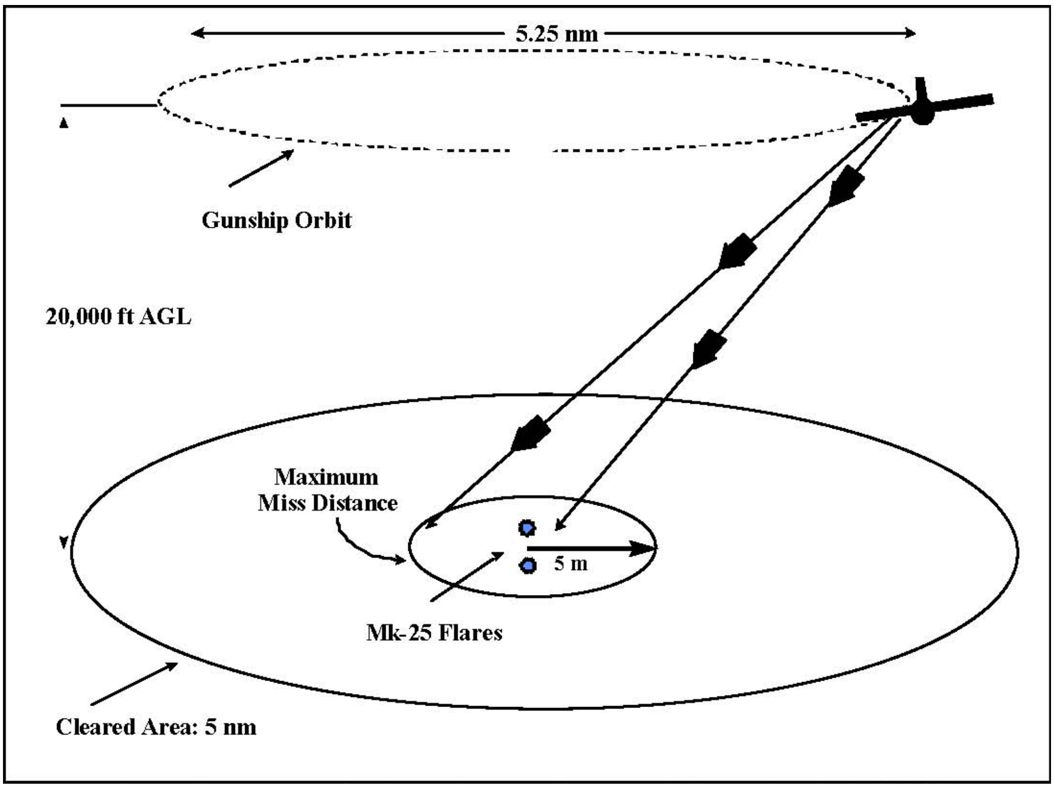

Figure 1-4. Typical Air-to-Surface Gunnery Mission in the EGTTR

Gunnery testing addressed in this request includes expected ordnance use for daytime and nighttime gunnery missions. The quantity of live rounds expended is based on recent (2010) estimates provided by the Air Force regarding the annual number of missions and number of rounds per mission. Full Up 105-mm rounds would be used during daytime missions, while 105-mm training rounds would be used during nighttime missions. The total anticipated number of missions and rounds expended for both daytime and nighttime activities are shown in Table 1-1.

Table 1-1. Yearly Summary of EGTTR Gunnery Nighttime and Daytime Operations

Category	Expendable	Number of Missions	Rounds per Mission	Quantity
Daytime Missions	105 mm FU	25	30	750
	40 mm HE	25	64	1,600
	25 mm HE	25	560	14,000
Nighttime Missions	105 mm TR	45	30	1,350
	40 mm HE	45	64	2,880
	25 mm HE	45	560	25,200
TOTAL		**70**		**45,780**

HE = High Explosive; TR = Training Round; FU = Full Up

2. DURATION AND LOCATION OF THE ACTIVITIES

Gunnery mission activities are conducted in the W-151 ranges, and predominantly in W-151A (Figure 1-2 and Figure 1-3). Missions may occur any time of year, during daytime or nighttime hours. Figure 2-1 shows where the 200-m isobath is located within W-151A. A boundary has been drawn between coordinates N 29° 42.73' W-86° 48.27' and N 29° 12.73' W-85° 59.88'. Of the 70 total missions proposed to occur each year, only one will occur south of that boundary in waters deeper than the 200-m isobath. All other missions will occur north of the boundary.

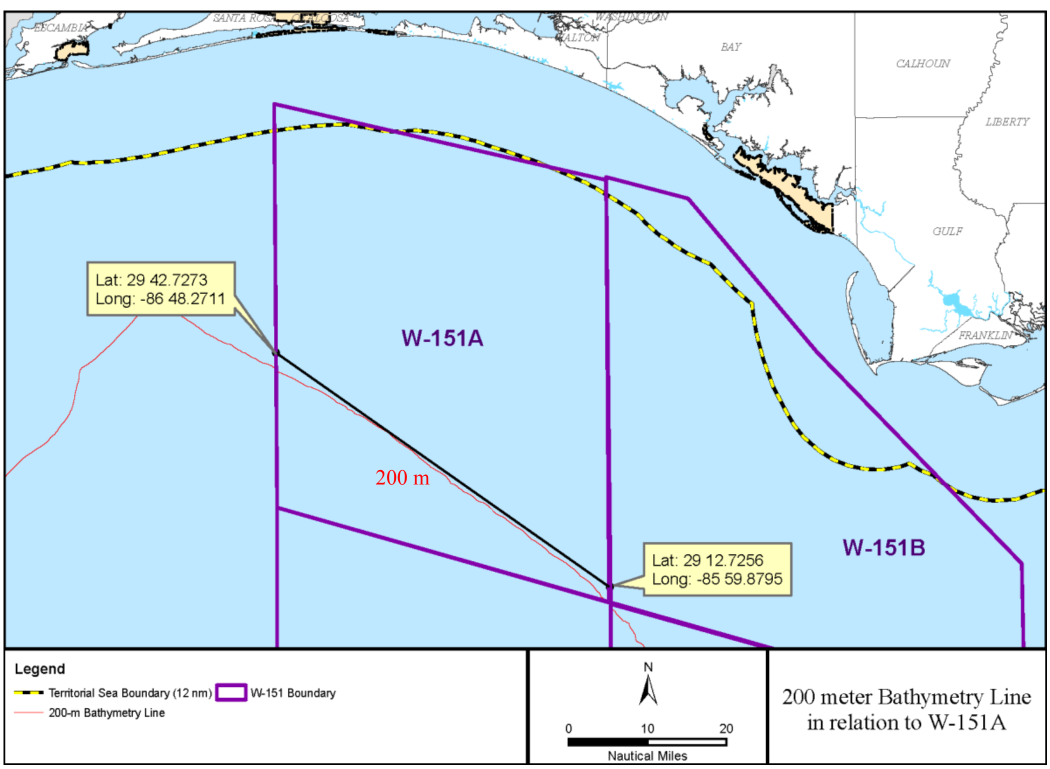

Figure 2-1. 200-m Isobath Boundary Within W-151A

The area in which air-to-surface gunnery activities may occur is referred to in the remainder of this document as the study area. Descriptive information for all of W-151 and for W-151A is provided below.

W-151

The inshore and offshore boundaries of W-151 are roughly parallel to the shoreline contour. The shoreward boundary is 3 NM from shore, while the seaward boundary extends approximately 85 to 100 NM offshore, depending on the specific location. W-151 covers a surface area of approximately 10,247 square nautical miles [NM^2] (35,145 square kilometers [km^2]), and includes water depths ranging from approximately 35 to 700 meters. This range of depth includes continental shelf and slope waters. Approximately half of W-151 lies over the shelf.

W-151A

W-151A extends approximately 60 NM offshore and has a surface area of 2,565 NM^2 (8,797 km^2). Water depths range from approximately 35 to 350 meters and include continental shelf and slope zones. However, most of W-151A occurs over the continental shelf, in water depths less than 250 m.

3. MARINE MAMMALS SPECIES AND NUMBERS

Marine mammals that potentially occur within the northeastern Gulf of Mexico (GOM) include numerous species of cetaceans and one sirenian, the West Indian manatee. During winter months, manatee distribution in the GOM is generally confined to southern Florida. During summer months, a portion of the population migrates north as far as Louisiana and Texas. However, manatees primarily inhabit coastal and inshore waters, and rarely sighted offshore. Eglin's gunnery missions may be conducted as close as 3 miles from shore, but more frequently occur offshore as far as 15 miles offshore. Therefore, effects on manatees are considered unlikely, and further discussion of marine mammal species is limited to cetaceans.

There are 29 cetacean species with possible or confirmed occurrence in the study area. Of these, 22 species occur with some level of regularity. The remaining seven species are currently considered extralimital or rare, and are not discussed further in this document. These species include North Atlantic right whale, humpback whale, sei whale, fin whale, blue whale, minke whale, and True's beaked whale.

With one exception, marine mammal density estimates used in this document are consistent with those provided in a recent LOA request and LOA addendum for Navy actions conducted offshore of Naval Surface Warfare Center Panama City Division (refer to the NMFS' 2010 issuance of LOA, 75 FR, No. 13, January 21, 2010). The geographic area covered by that LOA overlaps the area associated with air-to-surface gunnery activities, and is considered applicable for the purpose of estimating impacts in this document. The exception is the bottlenose dolphin, for which density estimates were recently provided through a Department of Defense-funded study. This study is described later in this section.

For all species other than the bottlenose dolphin, density estimates were derived from the *Navy OPAREA Density Estimates (NODE) for the GOMEX OPAREA* report (DON, 2007). Densities were determined by one of two methods: 1) model-derived estimates, or 2) Stock Assessment Report or other literature-derived estimates. For the model-based approach, density estimates were calculated for each species within areas containing survey effort. A relationship between these density estimates and associated environmental parameters such as depth, slope, distance from the shelf break, sea surface temperature, and chlorophyll *a* concentration was formulated using generalized additive models. This relationship was then used to generate a two-dimensional density surface for the region by predicting densities in areas where no survey data exist. All analyses for cetaceans in the GOM were based on data collected through NMFS-SEFSC shipboard surveys conducted between 1996 and 2004. Species-specific density estimates derived through spatial modeling were compared with abundance estimates found in the most current Stock Assessment Report to ensure consistency. All spatial models and density estimates used in the Navy 2010 LOA were reportedly reviewed by NMFS technical staff.

Cetacean density estimates provided by various researchers often do not contain adjustments for perception or availability bias. Perception bias refers to the failure of observers to detect animals, although they are present in the survey area and available to be seen. Availability bias refers to animals that are in the survey area, but are not able to be seen because they are submerged when observers are present. Perception bias and availability bias result in the underestimation of abundance and density numbers (negative bias). The density estimates provided in the NODE report are not corrected for negative bias and therefore likely underestimate density. In order to address potential negative bias, Eglin AFB has adjusted density estimates by use of submergence factors. Although submergence time versus surface time probably varies between and among species populations based on geographic location, season, and other factors, submergence times suggested by Moore and Clarke (1998) are used in this document.

Bottlenose dolphin density estimates are derived from *Protected Species Habitat Modeling in the Eglin Gulf Test and Training Range* (Garrison, 2008). The NMFS developed habitat models using recent aerial survey line transect data collected during winter (February 2007; water temperatures of 12-15°Celsius) and summer (July/August 2007; water temperatures >26°Celsius). In combination with remotely sensed habitat parameters (sea surface temperature and chlorophyll), these data were used to develop spatial density models for cetaceans within the continental shelf and coastal waters of the eastern GOM. Encounter rates during the aerial surveys were corrected for sighting probabilities and the probability that animals were available on the surface to be seen. Given that the survey area completely overlaps the present study area and that these survey data are the most recent and best available, these models are considered to best reflect the occurrence of bottlenose dolphins within the study area. Density estimates were calculated for a number of subareas within the EGTTR, and also aggregated into four principal area categories: North-Inshore, South-Inshore, North-Offshore, and South-Offshore. Gunnery missions will occur within W-15, which is located in the northernmost portion of the EGTTR (Figure 1-2 and Figure 1-3). Therefore, densities in the northern areas are considered most applicable. In order to provide conservative impact estimates, the greatest density between summer and winter seasons was chosen. Densities for northern inshore (shoreline to 20 meter water depth) and offshore (20 to 200 meter water depth) strata were averaged, resulting in an overall density estimate of 0.6319 bottlenose dolphins per square kilometer (km^2) to be used in this document.

Most of the cetaceans occurring in the study area are odontocetes. Very few baleen whales occur in the Gulf and most would not be expected to occur within the study area given the known distribution of these species. Within the bulk of the EGTTR, over the west Florida continental shelf, the most common species is the bottlenose dolphin (*Tursiops truncatus*) (Garrison 2008), and the Atlantic spotted dolphin (*Stenella frontalis*) also occurs commonly over the continental shelf (Fulling et al. 2003). In the continental slope waters covered by the EGTTR between the 200 m and 2000 m isobaths, the most common species include bottlenose dolphins, spinner dolphins (*Stenella longirostris*), and pantropical spotted dolphins (*Stenella attenuata*) in the deeper part of this area. In addition, the endangered sperm whale (*Physeter macrocephalus*) occupies waters near the 2,000 m isobath and a small population of Bryde's whales (*Balaenoptera edeni*) occupies waters along the 200 m isobath in the northeastern corner of the region (Mullin and Fulling 2004). Table 3-1 lists the cetacean species with a reasonable likelihood of occurrence in the study area, density estimates used in the 2010 Navy LOA, and density estimates adjusted for submergence time. For conservative analysis, the greatest density between summer and winter is used.

Table 3-1. Cetacean Density Estimates within the Study Area

Species	Density (animals/km^2)	Dive Profile (% of time at surface)	Adjusted Density (animals/km^2)
Bryde's whale	0.000035	20	0.000175
Sperm whale	0.000335	10	0.003345
Dwarf/Pygmy sperm whale	0.000381	20	0.001905
All beaked whales	0.000001	10	0.000013
Killer whale	0.000117	30	0.000387
Pygmy killer whale	0.000357	30	0.001189
False killer whale	0.000907	30	0.003023
Melon-headed whale	0.003015	30	0.010050
Short-finned pilot whale	0.002087	30	0.006857
Rough-toothed dolphin	0.000389	30	0.001295
Bottlenose dolphin	0.631900	n/a*	0.631900
Risso's dolphin	0.003632	30	0.012107
Atlantic spotted dolphin	0.105700	30	0.352333
Pantropical spotted dolphin	0.042870	30	0.142900
Striped dolphin	0.009272	30	0.030907
Spinner dolphin	0.038100	30	0.127000
Clymene dolphin	0.015160	30	0.050533
Fraser's dolphin	0.000634	30	0.002115
Totals	**0.854890**		**1.378034**

*Garrison (2008) provided an adjusted bottlenose dolphin density estimate, accounting for observer and availability bias

4. AFFECTED SPECIES STATUS AND DISTRIBUTION

Information on each marine mammal species considered in this document, including general descriptions, status, and occurrence, is provided below. Species listed as endangered or threatened under the Endangered Species Act of 1973 (ESA) are identified. In addition, in fulfillment of the MMPA, the NMFS has identified certain cetacean stocks as strategic. A "strategic stock" is a marine mammal stock considered likely to be listed under the ESA, currently listed under the ESA, currently listed as depleted under the MMPA, or for which the level of non-natural mortality or serious injury (e.g. from commercial fishing) exceeds the potential biological removal (PBR) level. PBR is defined as the maximum number of animals that may be removed, not including natural mortalities, from a stock while allowing the stock to reach or maintain its optimal sustainable population. This metric is provided for each of the affected species described below. Species descriptions and other information, unless otherwise noted, are taken from the most recent U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessment Reports, which are available on the NMFS Office of Protected Resources website. Where available, specific information on occurrence within the EGTTR Study Area is provided; otherwise, general occurrence predictions are made based on the descriptions in the Stock Assessment Reports.

Distribution of cetaceans in the Gulf is influenced by hydrographic and bathymetric features. The dominant hydrographic feature in the Gulf is the Loop Current that, though generally south of the continental slope, can generate anti-cyclonic (clockwise circulating) and cyclonic (counterclockwise) eddies that move onto or influence the slope and shelf regions. Davis et al. (2000) noted during 1997-98 surveys of the northern Gulf of Mexico that cetaceans were concentrated along the continental slope and in or near cyclonic eddies. Cetaceans may also be associated with seafloor features such as the DeSoto Canyon, Florida Escarpment, Mississippi Canyon, and Mississippi River Delta. These and other bathymetric features are shown on Figure 4-1.

4.1 BALEEN WHALES

Bryde's whale **(*Balaenoptera edeni*)**

Description – Bryde's whales can be easily confused with sei whales. Bryde's whales usually have three prominent ridges on the rostrum (other rorquals generally have only one) (Jefferson et al., 1993). The Bryde's whale's dorsal fin is tall and falcate and generally rises abruptly out of the back. Adults can be up to 15.5 m (50.9 ft) in length (Jefferson et al., 1993), but there is a smaller "dwarf" species that rarely reaches over 10 m (33 ft) in length (Jefferson, 2006).

Status – The best estimate of abundance for the Bryde's whale in the northern GOM is 40 individuals (Mullin and Fulling, 2004; Waring et al., 2006). It has been suggested that the Bryde's whales found in the GOM may represent a resident stock (Schmidly, 1981), but there is no information on stock differentiation (Waring et al., 2006). The NOAA Stock Assessment

Report provisionally considers the GOM population a separate stock from the Atlantic Ocean stock(s) (Waring et al., 2006). The stock is not strategic and the PBR is 0.1 whales.

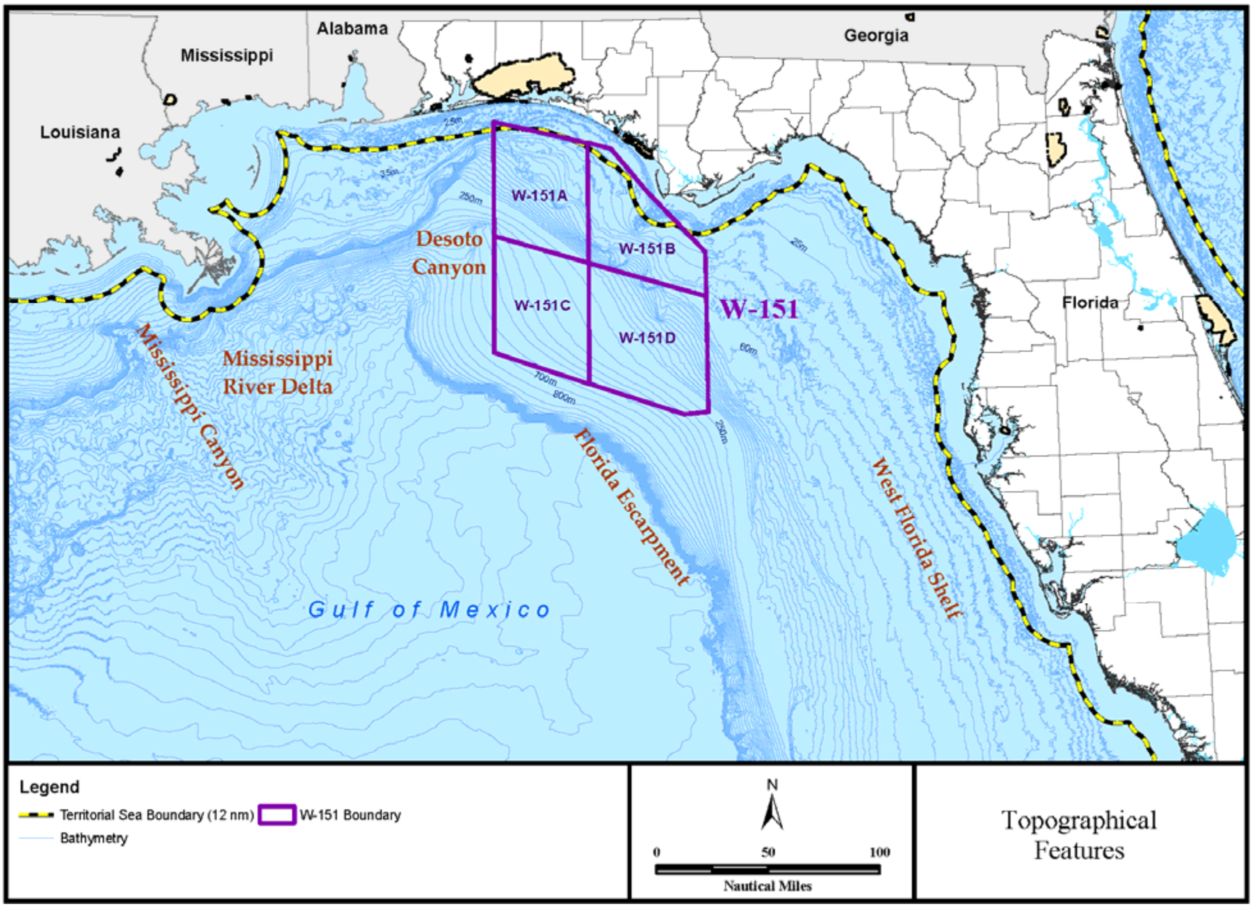

Figure 4-1. Topographical Features of the Gulf of Mexico

Diving Behavior – Bryde's whales are lunge-feeders, feeding on schooling fish and krill (Nemoto and Kawamura, 1977; Siciliano et al., 2004; Anderson, 2005). Cummings (1985) reported that Bryde's whales may dive as long as 20 minutes.

Acoustics and Hearing – Bryde's whales produce low frequency tonal and swept calls similar to those of other rorquals (Oleson et al., 2003). Calls vary regionally, yet all but one of the call types has a fundamental frequency below 60 Hertz (Hz). They last from one-quarter of a second to several seconds and are produced in extended sequences (Oleson et al., 2003). Heimlich et al. (2005) recently described five tone types. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Distribution – Bryde's whales are found in subtropical and tropical waters and generally do not range north of 40° in the northern hemisphere or south of 40° in the southern hemisphere (Jefferson et al., 1993). Bryde's whales are not often sighted in the GOM, though they are observed more frequently than any other species of baleen whale in this region. Sightings have primarily been recorded in the region of the DeSoto Canyon and over the Florida Escarpment

(Mullin et al., 1994; Davis and Fargion, 1996; Davis et al., 2000). This species may occur in the area during any season (Würsig et al., 2000).

During the winter, the greatest likelihood for encountering Bryde's whales is over the Florida Escarpment. In the springtime, Bryde's whales are predicted to occur in the area of the shelf break in a region that includes DeSoto Canyon and part of the Florida Escarpment. The highest Bryde's whale concentrations are thought to be discrete areas in the DeSoto Canyon and over the Florida Escarpment. In the summer, the greatest likelihood for encountering Bryde's whales is in a small region over the Florida Escarpment. During the fall, there are a few stranding records which reveal that the species is occasionally present during this season. Weather conditions (i.e., inclement weather increasing) could make sighting this species during the fall difficult and could explain why there are no recorded sightings.

Occurrence in the Study Area – Although Bryde's whales occur within in the study area seaward of the shelf break (approximately 200 meters water depth), density is expected to be low due to the limited number of individuals present in the GOM. Occurrence in W-151A, the most heavily used portion of the range, would be limited to the southwestern corner south of the 200-m isobath boundary as shown in Figure 2-1.

4.2 TOOTHED WHALES AND DOLPHINS

Atlantic bottlenose dolphin (*Tursiops truncatus*)

Description – Bottlenose dolphins are large and robust, varying in color from light gray to charcoal. The genus *Tursiops* is named for its short, stocky snout that is distinct from the melon (Jefferson et al., 1993). The dorsal fin is tall and falcate. There are striking regional variations in body size, with adult lengths from 1.9 to 3.8 m (6.2 to 12.5 ft) (Jefferson et al., 1993).

Scientists currently recognize a nearshore (coastal) and an offshore morphotype or form of bottlenose dolphins, which are distinguished by external and cranial morphology, hematology, diet, and parasite load (Duffield et al., 1983; Hersh and Duffield, 1990; Mead and Potter, 1995; Curry and Smith, 1997). There is also a clear genetic distinction between nearshore and offshore bottlenose dolphins worldwide (Curry and Smith, 1997; Hoelzel et al., 1998). It has been suggested that the two forms should be considered different species (Curry and Smith, 1997; Kingston and Rosel, 2004), but no official taxonomic revisions have been made.

Status –In the northern GOM, there are coastal stocks; a continental shelf stock; an oceanic stock; and 33 bay, sound, and estuarine stocks (Waring et al., 2006). Sellas et al. (2005) reported the first evidence that the coastal stock off west central Florida is genetically separated from the adjacent inshore areas. All bay, Sound, and estuarine stocks are designated as strategic. Other stocks are not considered strategic. PBR is 26 individuals for the Oceanic stock, but is undetermined for all other stocks.

There are three coastal stocks in the northern GOM that occupy waters from the shore to the 20-m (66-foot) isobath: Eastern Coastal, Northern Coastal, and Western Coastal (Waring et al., 2006). The Western Coastal stock inhabits the nearshore waters from the Texas/Mexico border to the Mississippi River mouth; the best estimate for this stock is 3,449 individuals (Waring et al., 2006). The Northern Coastal stock is defined from the Mississippi River mouth to approximately 84°W; the best estimate is 4,191 dolphins (Waring et al., 2006). The Eastern Coastal stock is defined from 84°W to Key West, Florida; the best estimate is 9,912 individuals (Waring et al., 2006).

The Continental Shelf stock is defined as dolphins inhabiting the waters from the Texas/Mexico border to Key West, Florida, between the 20- and 200-m (66- and 656-ft) isobaths (Waring et al., 2006). The best estimate of abundance for this stock is 25,320 bottlenose dolphins (Fulling et al., 2003; Waring et al., 2006). The continental shelf stock probably consists of a mixture of both the coastal and offshore ecotypes.

The Oceanic stock is provisionally defined as bottlenose dolphins inhabiting waters from the 200-m (656-ft) isobath to the seaward extent of the EEZ (Waring et al., 2006). The best estimate of abundance for the bottlenose dolphin in oceanic waters of the northern GOM is 2,239 individuals (Mullin and Fulling, 2004; Waring et al., 2006). This stock is believed to consist of the offshore form of bottlenose dolphins described by Hersh and Duffield (1990). Both inshore/coastal stocks and the oceanic stock are separate from the continental shelf stock; however, the continental shelf stock may overlap with coastal stocks and the oceanic stock in some areas and may be genetically indistinguishable from those other stocks (Waring et al., 2006).

Genetic, photo-identification, and tagging data support the concept of relatively discrete bay, sound, and estuarine stocks. Although the shoreward boundary of W-151 is beyond these environments, individuals from these stocks could potentially enter the study area. Movement between various communities has been documented (Waring et al., 2009), and Fazioli et al. (2006) demonstrated that dolphins found inshore within bays, sounds, and estuaries on the west central Florida coast move into the nearby Gulf waters used by coastal stocks. Air-to-surface gunnery activities occur geographically within an area considered to be occupied by five stocks: Pensacola/East Bay, Choctawhatchee Bay, St. Andrew Bay, St. Joseph Bay, and St. Vincent Sound/Apalachicola Bay/St. George Sound. All bay, Sound, and estuarine stocks are designated as strategic.

In the last few decades, there have been five unusual mortality events involving bottlenose dolphins in the GOM (NOAA and FFWCC, 2004). The most recent occurred between 10 March and 13 April 2004, in which 107 bottlenose dolphins dead stranded along the Florida Panhandle (NOAA and FFWCC, 2004). Analyses indicated that breve toxins and low levels of domoic acid were present in the stranded animals, possibly leading to the stranding event (NOAA and FFWCC, 2004; Flewelling et al., 2005).

Diving Behavior – Dive durations as long as 15 minutes are recorded for trained individuals (Ridgway et al., 1969). Typical dives, however, are more shallow and of a much shorter duration. Mean dive durations of Atlantic bottlenose dolphins typically range from 20 to 40 seconds at shallow depths (Mate et al., 1995) and can last longer than 5 minutes during deep offshore dives (Klatsky et al., 2005). Offshore bottlenose dolphins regularly dive to 450 m (1,476 ft) and possibly as deep as 700 m (2,297 ft) (Klatsky et al., 2005).

Acoustics and Hearing – Sounds emitted by bottlenose dolphins have been classified into two broad categories: pulsed sounds (including clicks and burst-pulses) and narrow-band continuous sounds (whistles), which usually are frequency modulated. Clicks and whistles have a dominant frequency range of 110 to 130 kiloHertz (kHz) and a source level of 218 to 228 dB re 1 µPa-m peak-to-peak (Au, 1993) and 3.4 to 14.5 kHz and 125 to 173 dB re 1 µPa-m peak-to-peak, respectively (Ketten, 1998). Whistles are primarily associated with communication and can serve to identify specific individuals (i.e., signature whistles) (Caldwell and Caldwell, 1965; Janik et al., 2006). Up to 52 percent of whistles produced by bottlenose dolphin groups with mother-calf pairs can be classified as signature whistles (Cook et al., 2004). Sound production is also influenced by group type (single or multiple individuals), habitat, and behavior (Nowacek, 2005). Bray calls (low-frequency vocalizations; majority of energy below 4 kHz), for example, are used when capturing fishes, specifically sea trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*), in some regions (i.e., Moray Firth, Scotland) (Janik, 2000). Additionally, whistle production has been observed to increase while feeding (Acevedo-Gutiérrez and Stienessen, 2004; Cook et al., 2004). Furthermore, both whistles and clicks have been demonstrated to vary geographically in terms of overall vocal activity, group size, and specific context (e.g., feeding, milling, traveling, and socializing) (Jones and Sayigh, 2002; Zaretsky et al., 2005; Baron, 2006).

Bottlenose dolphins can typically hear within a broad frequency range of 0.04 to 160 kHz (Au, 1993; Turl, 1993). Electrophysiological experiments suggest that the bottlenose dolphin brain has a dual analysis system: one specialized for ultrasonic clicks and another for lower-frequency sounds, such as whistles (Ridgway, 2000). Scientists have reported a range of highest sensitivity between 25 and 70 kHz, with peaks in sensitivity at 25 and 50 kHz (Nachtigall et al., 2000). Recent research on the same individuals indicates that auditory thresholds obtained by electrophysiological methods correlate well with those obtained in behavior studies, except at the some lower (10 kHz) and higher (80 and 100 kHz) frequencies (Finneran and Houser, 2006).

Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins using a variety of noises (i.e., broad-band, pulses) (Ridgway et al., 1997; Schlundt et al., 2000; Nachtigall et al., 2003; Finneran et al., 2005; Mooney et al., 2005; Mooney, 2006). For example, TTS has been induced with exposure to a 3 kHz, one-second pulse with sound exposure level (SEL) of 195 dB re 1 μPa^2-s (Finneran et al., 2005), one-second pulses from 3 to 20 kHz at 192 to 201 dB re 1µPa-m (Schlundt et al., 2000), and octave band noise (4 to 11 kHz) for 50 minutes at 179 dB re 1 µPa-m (Nachtigall et al., 2003). Preliminary research indicates that TTS and recovery after noise exposure are frequency dependent and that an inverse relationship exists between exposure time and sound pressure level associated with exposure (Mooney et al., 2005; Mooney, 2006). Observed changes in behavior were induced with an exposure to a 75 kHz one-second pulse at 178 dB re 1 µPa-m (Ridgway et al., 1997; Schlundt et al., 2000). Finneran et al. (2005) concluded that a SEL of 195 dB re 1 μPa^2 s is a reasonable threshold for the onset of TTS in bottlenose dolphins exposed to mid-frequency tones.

Distribution – The overall range of the bottlenose dolphin is worldwide in tropical and temperate waters. This species occurs in all three major oceans and many seas. In the western North Atlantic, bottlenose dolphins occur as far north as Nova Scotia but are most common in coastal waters from New England to Florida, the Gulf of Mexico, the Caribbean, and southward to Venezuela and Brazil (Würsig et al., 2000). Bottlenose dolphins occur seasonally in estuaries and coastal embayments as far north as Delaware Bay (Kenney, 1990) and in waters over the outer continental shelf and inner slope, as far north as Georges Bank (CETAP, 1982; Kenney, 1990).

The bottlenose dolphin is by far the most widespread and common cetacean in coastal waters of the GOM (Würsig et al., 2000). Bottlenose dolphins are frequently sighted near the Mississippi River Delta (Baumgartner et al., 2001) and have even been known to travel several kilometers up the Mississippi River.

Gulf of Mexico

Bottlenose dolphins are abundant in continental shelf waters throughout the northern GOM (Fulling et al., 2003; Waring et al., 2006). Mullin and Fulling (2004) noted that in oceanic waters, bottlenose dolphins are encountered primarily in upper continental slope waters (less than 1,000 m in bottom depth) and that highest densities are in the northeastern Gulf.

In the winter, bottlenose dolphins may occur on the outer continental shelf and upper slope of the western Gulf and nearshore waters in the north-central and north-eastern Gulf, as well as the DeSoto Canyon region and Florida Escarpment. The large number of sightings in shelf waters off Mississippi, Alabama, and the Florida Panhandle are a result of aerial surveys conducted here during this season. It is well-known that the bottlenose dolphin occurs in nearshore waters west of the Mississippi River or over most of the Florida Shelf throughout these areas year-round; the apparent absence of occurrence in these areas is biased by the lack of survey effort during this time of year.

In the spring, bottlenose dolphins occur on the outer continental shelf and upper slope of the western Gulf and nearshore waters in the north-central and north-eastern Gulf, as well as the DeSoto Canyon region and Florida Escarpment. The large number of sightings in shelf waters off Mississippi, Alabama, and the Florida Panhandle are a result of aerial surveys conducted here during this season. In summer, occurrence is predicted throughout the vast majority of shelf waters, as well as over the continental slope. Significant occurrences are anticipated near all bays in the northern Gulf.

Occurrence in the Study Area – The Atlantic bottlenose dolphin is the most abundant cetacean over the continental shelf and slope off the western Florida panhandle and is therefore expected to occur within the entire study area.

Atlantic spotted dolphin (*Stenella frontalis*)

Description – The Atlantic spotted dolphin has features that resemble bottlenose dolphins and pantropical spotted dolphins (Jefferson et al., 1993). In body shape, it is somewhat intermediate between the two, with a moderately long but rather thick beak. The dorsal fin is tall and falcate and there is generally a prominent spinal blaze. Adults are up to 2.3 m (7.5 ft) long and can weigh as much as 143 kg (315 lb) (Jefferson et al., 1993). Atlantic spotted dolphins are born spotless and develop spots as they age (Perrin et al., 1994; Dudzinski, 1996; Herzing, 1997). Some Atlantic spotted dolphin individuals become so heavily spotted that the dark cape and spinal blaze are difficult to see (Perrin et al., 1994; Dudzinski, 1996; Herzing, 1997).

There is marked regional variation in the adult body size of the Atlantic spotted dolphin (Perrin et al., 1987). There are two forms: a robust, heavily spotted form that inhabits the continental shelf, usually found within 250 to 350 km (135 to 189 NM) of the coast and a smaller, less-spotted form that inhabits offshore waters (Perrin et al., 1994). The largest body size occurs in waters over the continental shelf of North America (East Coast and Gulf of Mexico) and Central America (Perrin, 2002).

Status – The best estimate of abundance for the Atlantic spotted dolphin in the northern GOM is 30,947 individuals (Fulling et al., 2003; Mullin and Fulling, 2004; Waring et al., 2006). The northern GOM population was recently confirmed to be genetically differentiated from the western North Atlantic populations (Adams and Rosel, 2006). PBR for this species is undetermined. This is not considered a strategic stock

Diving Behavior – The only information on diving depth for this species is from a satellite-tagged individual in the Gulf of Mexico (Davis et al., 1996). This individual made short, shallow dives to less than 10 m (33 ft) and as deep as 60 m (197 ft), while in waters over the continental shelf on 76 percent of dives.

Acoustics and Hearing – A variety of sounds including whistles, echolocation clicks, squawks, barks, growls, and chirps have been recorded for the Atlantic spotted dolphin (Thomson and Richardson, 1995). Whistles have dominant frequencies below 20 kHz (range: 7.1 to 14.5 kHz) but multiple harmonics extend above 100 kHz, while burst pulses consist of frequencies above 20 kHz (dominant frequency of approximately 40 kHz) (Lammers et al., 2003). Other sounds, such as squawks, barks, growls, and chirps, typically range in frequency from 0.1 to 8 kHz (Thomson and Richardson, 1995). Recently recorded echolocation clicks have two dominant frequency ranges at 40 to 50 kHz and 110 to 130 kHz, depending on source level (i.e., lower source levels typically correspond to lower frequencies and higher frequencies to higher source levels (Au and Herzing, 2003). Echolocation click source levels as high as 210 dB re 1 µPa-m peak-to-peak have been recorded (Au and Herzing, 2003). Spotted dolphins in The Bahamas were frequently recorded during agonistic/aggressive interactions with bottlenose dolphins (and their own species) to produce squawks (0.2 to 12 kHz broad band burst pulses; males and females), screams (5.8 to 9.4 kHz whistles; males only), barks (0.2 to 20 kHz burst pulses; males only), and synchronized squawks (0.1-15 kHz burst pulses; males only in a coordinated group) (Herzing, 1996).

There has been no data collected on Atlantic spotted dolphin hearing ability. However, odontocetes are generally adapted to hear high-frequencies (Ketten, 1997).

Distribution – Atlantic spotted dolphins are distributed in warm-temperate and tropical Atlantic waters from approximately 45º N to 35º S; in the western North Atlantic, this translates to waters from northern New England to Venezuela, including the Gulf of Mexico and the Caribbean Sea (Perrin et al., 1987). Atlantic spotted dolphins may occur in both continental shelf and offshore waters (Perrin et al., 1994). Known densities of Atlantic spotted dolphins are highest in the eastern GOM, east of Mobile Bay (Fulling et al., 2003). Atlantic spotted dolphins in the northern GOM are abundant in continental shelf waters (Fulling et al., 2003; Waring et al., 2006). In oceanic waters, this species usually occurs near the shelf break and upper continental slope waters (Davis et al., 1998; Mullin and Hansen, 1999).

Gulf of Mexico

Atlantic spotted dolphins in the northern GOM are abundant in continental shelf waters (Fulling et al., 2003; Waring et al., 2006). In oceanic waters, this species usually occurs near the shelf break and upper continental slope waters (Davis et al., 1998; Mullin and Hansen, 1999). Atlantic spotted dolphins are most abundant in the eastern GOM (Fulling et al., 2003). On the West Florida shelf, spotted dolphins are more common in deeper waters than bottlenose dolphins (Griffin and Griffin, 2003); Griffin and Griffin (2004) reported higher densities of spotted dolphins in this area during November through May.

In winter, there may be occurrence in waters over the continental shelf and along the shelf break throughout the entire northern GOM. Stranding data suggest that this species may be more common than the survey data demonstrate.

Occurrence during spring is primarily in the vicinity of the shelf break from central Texas to southwestern Florida. Sighting data reflect high usage of the Florida Shelf by this species.

In summer, occurrence is primarily in waters over the continental shelf, along the shelf break throughout the entire northern GOM, and over the Florida Escarpment. Sighting data shows increased usage of the Florida Shelf, as well as the Florida Panhandle and inshore of DeSoto Canyon. An additional area of increased occurrence is predicted in shelf waters off western Louisiana.

In fall, the sighting data demonstrate occurrence in waters over the continental shelf and along the shelf break throughout the entire northern GOM. There are numerous sightings in the Mississippi River delta region and Florida Panhandle. This is the season with the least amount of systematic survey effort, and inclement weather conditions can make sighting cetaceans difficult during this time of year.

Occurrence in the Study Area – Atlantic spotted dolphins are relatively abundant over the continental shelf and slope off the western Florida panhandle and are therefore expected to occur within the entire study area.

Beaked Whales

Description – Four beaked whales have documented occurrence in the GOM, including Cuvier's beaked whale (*Ziphius cavirostris*) and three members of the genus *Mesoplodon*: Gervais' beaked whale (*Mesoplodon europaeus*), Blainville's beaked whale (*Mesoplodon densirostris*), and Sowerby's beaked whale (*Mesoplodon bidens*). The Smithsonian Institution is currently developing an online system to facilitate species-level identification of stranded individuals (Allen et al., 2005). They are presented here in one summary due to the paucity of biological information available for each species and the difficulty of species-level identifications for *Mesoplodon* species. *Mesoplodon* species are also often termed ”mesoplodonts.“

Cuvier's beaked whales are relatively robust compared to other beaked whale species. Male and female Cuvier's beaked whales may reach 7.5 and 7.0 m (24.6 and 23.0 ft) in length, respectively (Jefferson et al., 1993). This species has a relatively short beak, which along with the curved jaw, resembles a goose beak. The body is spindle shaped, and the dorsal fin and flippers are small which is typical for beaked whales. A useful diagnostic feature is a concavity on the top of the head, which becomes more prominent in older individuals. Cuvier's beaked whales are dark gray to light rusty brown in color, often with lighter color around the head. In adult males, the head and much of the back can be light gray to white in color, and they also often have many light scratches and circular scars on the body (Jefferson et al., 1993).

All mesoplodonts have a relatively small head, large thorax and abdomen, and short tail. Mesoplodonts all have a pair of throat grooves on the ventral side of the head on the lower jaw. Mesoplodonts are characterized by the presence of a single pair of sexually dimorphic tusks, which erupt only in adult males. MacLeod (2000b) suggested that the variation in tusk position and shape acts as a species recognition signal for these whales.

Blainville's beaked whales are documented to reach a maximum length of around 4.7 m (15.4 ft) (Jefferson et al., 1993). Adults are blue-gray on their dorsal side and white below (Jefferson et al., 1993). The lower jaw of the Blainville's beaked whale is highly arched, and massive flattened tusks extend above the upper jaw in adult males (Jefferson et al., 1993).

Gervais' beaked whale males reach lengths of at least 4.5 m, while females reach at least 5.2 m (17.1 ft) (Jefferson et al., 1993). These beaked whales are dark gray dorsally with a light-gray belly. Adult males have one tooth evident per side, one-third of the distance from the snout tip to the corner of the mouth (Jefferson et al., 1993).

Sowerby's beaked whale males and females attain lengths of at least 5.5 and 5.1 m (18.0 and 16.7 ft), respectively (Jefferson et al., 1993). The beak is long and distinct. The melon also has a hump on the top. Two small teeth are evident along the middle of the lower jaw in adult males. Coloration has generally been described as charcoal gray dorsally and lighter below (Jefferson et al., 1993). Gray spotting has been noted on adults, although younger animals may also display a lesser degree of spotting (Jefferson et al., 1993).

Status – The best estimate of mesoplodont and Cuvier's beaked whale abundance combined in the western North Atlantic is 3,513 individuals (Waring et al., 2007). A recent study of global phylogeographic structure of Cuvier's beaked whales suggested that some regions show a high level of differentiation (Dalebout et al., 2005). However, it was not possible for this study to discern finer-scale population differences within the North Atlantic (Dalebout et al., 2005).
The best estimate of abundance for the Cuvier's beaked whale in the northern GOM is 95 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The best estimate of abundance for *Mesoplodon* spp. in the northern GOM is 106 individuals (Mullin and Fulling, 2004; Waring et al., 2006). Species-specific estimates have not been obtained due to the difficulty of identifying specimens at sea. The GOM Cuvier's beaked whale and *Mesoplodon* spp. populations are provisionally being considered as separate stocks for management purposes although there is currently no information to differentiate these stocks from the Atlantic Ocean stock(s) (Waring et al., 2006).

None of the beaked whale species are strategic. PBR for Cuvier's beaked whale in the northern Gulf of Mexico is 0.4. PBR for all *Mesoplodon* species in the northern Gulf is 0.2.

Diving Behavior – Dives range from those near the surface where the animals are still visible to long, deep dives. Dive durations for *Mesoplodon* spp. are typically over 20 minutes (Barlow, 1999; Baird et al., 2005). Tagged Cuvier's beaked whale dive durations as long as 87 minutes and dive depths of up to 1,990 m (6,529 ft) have been recorded (Baird et al., 2004; Baird et al., 2005). Tagged Blainville's beaked whale dives have been recorded to 1,408 m (4,619 ft) and lasting as long as 54 minutes (Baird et al., 2005). Baird et al. (2005) reported that several aspects of diving were similar between Cuvier's and Blainville's beaked whales: 1) both dove for 48 to 68 minutes to depths greater than 800 m (2,625 ft), with one long dive occurring on average every two hours; 2) ascent rates for long/deep dives were substantially slower than descent rates, while during shorter dives there were no consistent differences; and 3) both spent prolonged periods of time (66 to 155 minutes) in the upper 50 m (164 ft) of the water column. Both species make a series of shallow dives after a deep foraging dive to recover from oxygen debt; average intervals between foraging dives have been recorded as 63 minutes for Cuvier's beaked whales and 92 minutes for Blainville's beaked whales (Tyack et al., 2006).

Acoustics and Hearing **–** Sounds recorded from beaked whales are divided into two categories: whistles and pulsed sounds (clicks); whistles likely serve a communicative function and pulsed sounds are important in foraging and/or navigation (Johnson et al., 2004; Madsen et al., 2005) (MacLeod and D'Amico, 2006; Tyack et al., 2006). Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz; however, as noted by MacLeod and D'Amico (2006), higher frequencies may not be recorded due to equipment limitations. Whistles recorded from free-ranging Cuvier's beaked whales off Greece ranged in frequency from 8 to 12 kHz, with an upsweep of about 1 sec (Manghi et al., 1999), while pulsed sounds had a narrow peak frequency of 13 to 17 kHz, lasting 15 to 44 sec in duration (Frantzis et al., 2002). Short whistles and chirps from a stranded subadult Blainville's beaked whale ranged in frequency from slightly less than 1 to almost 6 kHz (Caldwell and Caldwell, 1971).

Recent studies incorporating DTAGs (miniature sound and orientation recording tag) attached to Blainville's beaked whales in the Canary Islands and Cuvier's beaked whales in the Ligurian Sea recorded high-frequency echolocation clicks (duration: 175 μs for Blainville's and 200 to 250 μs for Cuvier's) with dominant frequency ranges from about 20 to over 40 kHz (limit of recording system was 48 kHz) and only at depths greater than 200 m (656 ft) (Johnson et al., 2004; Madsen et al., 2005; Zimmer et al., 2005; Tyack et al., 2006). The source level of the Blainville's beaked whales' clicks were estimated to range from 200 to 220 dB re 1 μPa-m peak-to-peak (Johnson et al., 2004), while they were 214 dB re 1 μPa-m peak-to-peak for the Cuvier's beaked whale (Zimmer et al., 2005).

From anatomical examination of their ears, it is presumed that beaked whales are predominantly adapted to best hear ultrasonic frequencies (MacLeod, 1999; Ketten, 2000-ear adaptations). Beaked whales have well-developed semi-circular canals (typically for vestibular function but may function differently in beaked whales) compared to other cetacean species, and they may be more sensitive than other cetaceans to low-frequency sounds (MacLeod, 1999; Ketten, 2000-ear adaptations). Ketten (2000-ear adaptations) remarked on how beaked whale ears (computerized tomography (CT) scans of Cuvier's, Blainville's, Sowerby's, and Gervais' beaked whale heads) have anomalously well-developed vestibular elements and heavily reinforced (large bore, strutted) Eustachian tubes and noted that they may impart special resonances and acoustic sensitivities. The only direct measure of beaked whale hearing is from a stranded juvenile Gervais' beaked whale using auditory evoked potential (AEP) techniques (Cook et al., 2006). The hearing range was 5 to 80 kHz, with greatest sensitivity at 40 and 80 kHz (Cook et al., 2006).

Distribution – Cuvier's beaked whales are the most widely distributed of the beaked whales and are present in most regions of all major oceans (Heyning, 1989; MacLeod et al., 2006). This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas (MacLeod et al., 2006).

The ranges of most mesoplodonts are poorly known. In the western North Atlantic and Gulf of Mexico, these animals are known mostly from strandings (Mead, 1989; MacLeod, 2000a; MacLeod et al., 2006). Blainville's beaked whales are thought to have a continuous distribution throughout tropical, subtropical, and warm-temperate waters of the world's oceans; they occasionally occur in cold-temperate areas (MacLeod et al., 2006). The Gervais' beaked whale is restricted to warm-temperate and tropical Atlantic waters with records throughout the Caribbean Sea (MacLeod et al., 2006). The Gervais' beaked whale is the most frequently stranded beaked whale in the GOM (Würsig et al., 2000). The Sowerby's beaked whale is endemic to the North Atlantic; this is considered to be more of a temperate species (MacLeod et al., 2006). The stranding on the Gulf coast of Florida is considered to be extralimital (Jefferson and Schiro, 1997; MacLeod et al., 2006).

The continental shelf margins from Cape Hatteras to southern Nova Scotia were recently identified as known key areas for beaked whales in a global review by MacLeod and Mitchell (2006). Macleod and Mitchell (2006) described the northern GOM continental shelf margin as "a key area" for beaked whales.

Gulf of Mexico

Beaked whales are considered to be a deep water species. There are a handful of beaked whale sightings on the continental shelf off Mississippi and Alabama made during the Esher et al. (1992) surveys. Many surveys have taken place on the continental shelf in this region, yet this is the only survey program that recorded beaked whales. Two of the beaked whale sightings reported during the fall in the near vicinity of the shelf break are suspect with group sizes of 6 and 10 individuals, respectively. These are much larger group sizes than are typically reported. There is also one beaked whale sighting off Mobile Bay, Alabama, in waters with a bottom depth of approximately 30 m (98 ft). This could be a sighting of an individual which may have later stranded.

In the winter, sightings are in waters seaward of the shelf break, particularly over the continental slope. This is a time of year with both decreased survey effort and high sea states that can make sighting cetaceans (especially beaked whales) difficult. Occurrence should be expected in deep waters throughout the entire northern GOM.

The spring is the season with the most survey effort; sightings are throughout the deep waters of the northern GOM. Beaked whales are anticipated to occur throughout deep waters of the Gulf. The area of greatest concentration may occur over the abyssal plain at the southern edge of the GOM. Other patches of high concentrations may occur in waters over the Florida Escarpment and in the region influenced by the Tortugas Gyre.

In the summer, sightings are throughout most of the deep waters of the northern GOM. There may be patchy occurrence primarily in the central and eastern GOM, particularly in the Mississippi Canyon region and around parts of the Florida Escarpment. The areas of greatest concentration are in waters over the continental slope and abyssal plain south of Louisiana.

Fall is a season with a lesser amount of recorded sightings, likely due to decreased survey effort and high Beaufort sea states that can make sighting cetaceans difficult during this time of year. Occurrence should be expected in deep waters throughout the entire northern GOM.

Occurrence in the Study Area – Although strandings of beaked whales have been documented along the northwest Florida coast, these species appear to prefer water depths greater than those within the study area. Therefore, encounters with beaked whales during air-to-surface gunnery activities are considered unlikely.

Clymene dolphin (*Stenella clymene*)

Description – Due to similarity in appearance, Clymene dolphins are easily confused with spinner and short-beaked common dolphins (Fertl et al., 2003). The Clymene dolphin, however, is smaller and more robust, with a much shorter and stockier beak. The dorsal fin is tall and only slightly falcate. A three-part color pattern consisting of a dark gray cape, light gray sides, and white belly is characteristic of this species (Jefferson and Curry, 2003). The cape dips in two places, first above the eye and then below the dorsal fin. The lips and beak tip are black. There is also a dark stripe on the top of the beak, as well as a dark variably shaped "moustache" on the middle of the top of the beak. The Clymene dolphin can reach at least 2 m (7 ft) in length and weights of at least 85 kg (187 lb) (Jefferson et al., 1993).

Status – Clymene dolphins have only been recognized as a valid species since 1981 (Perrin et al., 1981). The best estimate of abundance for Clymene dolphins in the northern GOM is 17,355 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population of Clymene dolphins is provisionally being considered a separate stock for management purposes. The PBR for northern Gulf of Mexico is 49 dolphins and it is not considered a strategic stock (Waring et al., 2009).

Diving Behavior – There is no diving information available for this species.

Acoustics and Hearing – The only data available for this species is a description of their whistles. Clymene dolphin whistle structure is similar to that of other stenellids, but it is generally higher in frequency (range of 6.3 to 19.2 kHz) (Mullin et al., 1994).

There is no empirical data on the hearing ability of Clymene dolphins; however, the most sensitive hearing range for odontocetes generally includes high frequencies (Ketten, 1997).

Distribution – Clymene dolphins are known only from the subtropical and tropical Atlantic Ocean (Perrin and Mead, 1994; Fertl et al., 2003). In the western Atlantic Ocean, Clymene dolphins are known from New Jersey to Brazil, including the Gulf of Mexico and Caribbean Sea (Fertl et al., 2003; Moreno et al., 2005). Although it is not clear if the actual density is higher, there are more Clymene dolphin records from the GOM than from the rest of this species' range combined (Jefferson et al., 1995; Fertl et al., 2003).

Gulf of Mexico

The Clymene dolphin is a deep water species. Mullin and Hansen (1999) noted that the majority of sightings for this species in the Gulf are west of the Mississippi River. Two mass strandings of Clymene dolphins were reported in the Florida Keys: one in July 1983 and the other in December 1992 (Jefferson et al., 1995). Both mass strandings took place over the course of a few days; therefore, they appear as multiple stranding records for the two events since carcasses were collected over the course of a few days.

There are few records during the winter; this is likely more an artifact of sparse survey effort and typically poor sighting conditions (e.g., rough seas) during this time of the year, since there are no known seasonal shifts in occurrence for this species in the Gulf.

Spring is the time of the year with the most survey effort and occurrence is expected seaward of the shelf break in most of the area of the western and central Gulf, with extension into the Mississippi River Delta region and the DeSoto Canyon.

During summer, Clymene dolphins may occur in deeper waters south of the continental slope, extending from the western Louisiana to the Florida Panhandle. Fewer occurrence records are available for the summer than spring.

In the fall, there is one sighting in very deep waters and a handful of strandings that are primarily in the Florida Keys which reflect the species' occurrence in the Gulf during this time of the year. No seasonality in occurrence is known for this species; anticipated occurrence is waters seaward of the shelf break.

Occurrence in the Study Area – Due to the prevalence of sightings west of the Mississippi River outflow and apparent preference for deeper waters, Clymene dolphins are not likely to be encountered during air-to-surface gunnery activities.

Dwarf sperm whale (*Kogia sima*) and Pygmy sperm whale (*Kogia breviceps*)

Description – There are two species of *Kogia*: the pygmy sperm whale and the dwarf sperm whale. Recent genetic evidence suggests that there might be an Atlantic and a Pacific species of dwarf sperm whales; however, more data are needed to make such a determination (Chivers et al., 2005).

Pygmy sperm whales have a shark-like head with a narrow, underslung lower jaw (Jefferson et al., 1993). The flippers are set high on the sides near the head. The small falcate dorsal fin of the pygmy sperm whale is usually set well behind the midpoint of the back (Jefferson et al., 1993). The dwarf sperm whale is similar in appearance to the pygmy sperm whale, but it has a larger dorsal fin that is generally set nearer the middle of the back (Jefferson et al., 1993). The dwarf sperm whale also has a shark-like profile but with a more pointed snout than the pygmy sperm whale. Pygmy and dwarf sperm whales reach body lengths of around 3 and 2.5 m (10 to 8 ft), respectively (Plön and Bernard, 1999).

Pygmy and dwarf sperm whales are difficult for the inexperienced observer to distinguish from one another at sea, and sightings of either species are often categorized as *Kogia* spp. The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction towards ships and change in behavior towards approaching survey aircraft (Würsig et al., 1998). Based on the cryptic behavior of these species and their small group sizes (much like that of beaked whales), as well as similarity in appearance, it is difficult to identify these whales to species in sightings at sea.

Status – There is currently no information to differentiate the Northern GOM stock from the Atlantic stock(s) (Waring et al., 2006), although they are provisionally considered separate stocks for management purposes. The best estimate of abundance for *Kogia* spp. in the GOM is 742 individuals (Mullin and Fulling, 2004; Waring et al., 2006). A separate estimate of abundance for the pygmy sperm whale or the dwarf sperm whale cannot be calculated due to uncertainty of species identification at sea (Waring et al., 2006). The stocks are not strategic. PBR for both species combined is 3.4. PBR is currently not determined for the species separately.

Diving Behavior – Willis and Baird (1998) reported that whales of the genus *Kogia* make dives of up to 25 minutes. Dive times ranging from 15 to 30 minutes (with 2 minute surface intervals) have been recorded for a dwarf sperm whale in the Gulf of California (Breese and Tershy, 1993). Median dive times of around 11 minutes are documented for *Kogia* (Barlow, 1999). A satellite-tagged pygmy sperm whale released off Florida was found to make long nighttime dives, presumably indicating foraging on squid in the deep scattering layer (Scott et al., 2001). Most sightings of *Kogia* are brief; these whales are often difficult to approach, and they sometimes actively avoid aircraft and vessels (Würsig et al., 1998).

Acoustics and Hearing – There is little published information on sounds produced by *Kogia* spp, although they are categorized as non-whistling smaller toothed whales. Recently, free-ranging dwarf sperm whales off La Martinque (Lesser Antilles) were recorded producing clicks at 13 to 33 kHz with durations of 0.3 to 0.5 sec (Jérémie et al., 2006). The only sound recordings for the pygmy sperm whale are from two stranded individuals. A stranded individual being prepared for release in the western North Atlantic emitted clicks of narrowband pulses with a mean duration of 119 μsec, interclick intervals between 40 and 70 msec, centroid frequency of 129 kHz, peak frequency of 130 kHz, and apparent source level of up to 175 dB re 1 μPa-m (Madsen et al., 2005). Another individual found stranded in Monterey Bay produced echolocation clicks ranging from 60 to 200 kHz, with a dominant frequency of 120 to 130 kHz (Ridgway and Carder, 2001).

No information on sound production or hearing is available for the dwarf sperm whale. An ABR study completed on a stranded pygmy sperm whale indicated a hearing range of 90 to 150 kHz (Ridgway and Carder, 2001).

Distribution – *Kogia* species apparently have a worldwide distribution in tropical and temperate waters (Jefferson et al., 1993). *Kogia* spp. generally occur along the continental shelf break and over the continental slope in the GOM (Baumgartner et al., 2001; Fulling and Fertl, 2003).

Gulf of Mexico

Kogia spp. generally occur along the continental shelf break and over the continental slope in the GOM (Baumgartner et al., 2001; Fulling and Fertl, 2003).

In the winter, *Kogia* spp. are found throughout the northern Gulf, seaward of the shelf break. This is a time of year that is typically data deficient for deep water cetaceans in the Gulf because there is little survey effort. It is also the time when inclement weather conditions occur, and since *Kogia* spp. are low to the water, they can be difficult to sight in rough seas.

During the spring and summer, *Kogia* spp. may occur throughout most of the deep water sections of the Gulf. There is a concentration of records near the south-central edge of the GOM based on sighting records in the spring and two sites of concentrated occurrence records near the south-central edge of the study area and directly south of Louisiana over the continental slope in the summer.

In the fall, there are sightings within the Mississippi Canyon and DeSoto Canyon regions which indicate that, as expected, this region is important habitat for this species.

Occurrence in the Study Area – *Kogia* species are expected occur within W-151, although occurrence in W-151A (the most frequently used portion of the range) is much less likely.

False killer whale (*Pseuorca crassidens*)

Description – The false killer whale is a large, dark gray to black dolphin with a faint gray patch on the chest and sometimes light gray areas on the head (Jefferson et al., 1993). The false killer whale has a long slender body, a rounded overhanging forehead, and little or no beak (Jefferson et al., 1993). The dorsal fin is falcate and slender. The flippers have a characteristic hump on the S-shaped leading edge—this is perhaps the best characteristic for distinguishing this species from the other “blackfish” (an informal grouping that is often taken to include pygmy killer, melon-headed, and pilot whales; Jefferson et al., 1993). Individuals reach maximum lengths of 6.1 m (20.0 ft) (Jefferson et al., 1993).

Status – There are no abundance estimates available for this species in the western North Atlantic (Waring et al., 2007). The best estimate of abundance for false killer whales in the northern GOM is 1,038 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population is provisionally considered a separate stock for management purposes, although there is currently no information to distinguish this stock from Atlantic Ocean stock(s). The species is not strategic. PBR for the northern Gulf of Mexico false killer whale is 5.0 animals.

Diving Behavior – Few diving data are available, although individuals are documented to dive as deep as 500 m (1,640 ft) (Odell and McClune, 1999). Shallower dive depths (maximum of 53 m

[174 ft]; averaging from 8 to 12 m [26 to 39 ft]) have been recorded for false killer whales in Hawaiian waters.

Acoustics and Hearing – Dominant frequencies of false killer whale whistles are from 4 to 9.5 kHz, and those of their echolocation clicks are from either 20 to 60 kHz or 100 to 130 kHz depending on ambient noise and target distance (Thomson and Richardson, 1995). Click source levels typically range from 200 to 228 dB re 1 µPa-m peak-to-peak (Ketten, 1998). Recently, false killer whales recorded in the Indian Ocean produced echolocation clicks with dominant frequencies of about 40 kHz and estimated source levels of 201-225 dB re 1 µPa-m peak-to-peak (Madsen et al., 2004b).

False killer whales can hear frequencies ranging from approximately 2 to 115 kHz with best hearing sensitivity ranging from 16 to 64 kHz (Thomas et al., 1988). Additional behavioral audiograms of false killer whales support a range of best hearing sensitivity between 16 and 24 kHz, with peak sensitivity at 20 kHz (Yuen et al., 2005). The same study also measured audiograms using the ABR technique, which came to similar results, with a range of best hearing sensitivity between 16 and 22.5 kHz, peaking at 22.5 kHz (Yuen et al., 2005). Behavioral audiograms in this study consistently resulted in lower thresholds than those obtained by ABR.

Distribution – False killer whales are found in tropical and temperate waters, generally between 50°S and 50°N latitude with a few records north of 50°N in the Pacific and the Atlantic (Baird et al., 1989; Odell and McClune, 1999). False killer whales are primarily offshore animals, although they do come close to shore, particularly around oceanic islands (Baird, 2002). Most sightings in the Gulf of Mexico have been made in oceanic waters greater than 200 m (656 ft) deep, although there are some sightings in waters over the continental shelf (Davis and Fargion, 1996). Inshore movements are occasionally associated with movements of prey and shoreward flooding of warm ocean currents (Stacey et al., 1994).

Gulf of Mexico

Most sightings in the Gulf of Mexico have been made seaward of the shelf break, although there are also sightings from over the continental shelf (Davis and Fargion, 1996; Jefferson and Schiro, 1997; Mullin and Fulling, 2004). Mullin and Hansen (1999) and Mullin and Fulling (2004) reported that most NMFS-SEFSC sightings were east of the Mississippi River. There is the possibility of encountering false killer whales between the 50-m (164-ft) isobath and the shelf break based on the fact that false killer whales sometimes make their way into shallower waters, as well as the many sightings reported by sport fishermen in the mid-1960s of “blackfish” (most likely false killer whales based on the descriptions) in waters offshore of Pensacola and Panama City, Florida (Brown et al., 1966). There were also occasional reports of fish stealing by these animals (the false killer whale frequently has been implicated in such fishery interactions). No seasonal differences in the occurrence patterns of this species are expected in the GOM.

Occurrence in the Study Area – Although false killer whales occur in the GOM within water depths found in W-151, encounters are considered unlikely due to the relatively low number of sightings and associated density in the northeastern GOM.

Melon-headed whale (*Peponocephala electra*)

Description – Melon-headed whales at sea closely resemble pygmy killer whales; both species have a blunt head with little or no beak. Melon-headed whales have pointed (versus rounded) flippers and a more triangular head shape than pygmy killer whales (Jefferson et al., 1993). The body is charcoal gray to black, with unpigmented lips (which often appear light gray, pink, or white) and a white urogenital patch (Perryman et al., 1994). This species also has a triangular face "mask" and indistinct cape (which dips much lower below the dorsal fin than that of pygmy killer whales). Melon-headed whales reach a maximum length of 2.75 m (9.02 ft) (Jefferson et al., 1993).

Status – There are no abundance estimates for melon-headed whales in the western North Atlantic (Waring et al., 2007). The best estimate of abundance for melon-headed whales in the northern GOMEX is 2,283 individuals (Waring et al., 2008).

Diving Behavior – Melon-headed whales prey on squids, pelagic fishes, and occasionally crustaceans. Most fish and squid prey are mesopelagic in waters up to 1,500 m deep, suggesting that feeding takes place deep in the water column (Jefferson and Barros, 1997). There is no information on specific diving depths for melon-headed whales.

Acoustics and Hearing – The only published acoustic information for melon-headed whales is from the southeastern Caribbean (Watkins et al., 1997). Sounds recorded included whistles and click sequences. Recorded whistles have dominant frequencies between 8 and 12 kHz; higher-level whistles were estimated at no more than 155 dB re 1 µPa-m (Watkins et al., 1997). Clicks had dominant frequencies of 20 to 40 kHz; higher-level click bursts were estimated to be about 165 dB re 1 µPa-m (Watkins et al., 1997). No empirical data on hearing ability for this species are available.

Distribution – Melon-headed whales occur worldwide in subtropical and tropical waters. There are very few records for melon-headed whales in the North Atlantic (Ross and Leatherwood, 1994; Jefferson and Barros, 1997). Maryland is thought to represent the extreme of the northern distribution for this species in the northwest Atlantic (Perryman et al., 1994; Jefferson and Barros, 1997). The first two occurrence records for this species in the GOMEX were strandings in Texas and Louisiana during 1990 and 1991, respectively (Barron and Jefferson, 1993).

Gulf of Mexico

The melon-headed whale is an oceanic species; this is confirmed by the distribution of sighting records, which show the species to occur in waters seaward of the shelf break. Mullin and Hansen (1999) noted that melon-headed whales appear to be more frequently sighted west of the Mississippi River. No seasonality to their occurrence is expected. The large number of sightings during the spring is due to high survey coverage during this time of year.

Occurrence in the Study Area – Encounters with melon-headed whales during air-to-surface gunnery activities is considered unlikely due to the low number of sightings and deep water locations of sightings.

Pantropical spotted dolphin (*Stenella attenuata*)

Description – The pantropical spotted dolphin is a rather slender dolphin. This species has a dark dorsal cape, while the lower sides and belly of adults are gray. The beak is long and thin; the lips and beak tip tend to be bright white. A dark gray band encircles each eye and continues forward to the apex of the melon; there is also a dark gape-to-flipper stripe (Jefferson et al., 1993). Pantropical spotted dolphins are born spotless and develop spots as they age although the degree of spotting varies geographically (Perrin and Hohn, 1994). Some populations may be virtually unspotted (Jefferson, 2006). Adults may reach 2.6 m (8.5 ft) in length (Jefferson et al., 1993).

Status – The best estimate of abundance for the pantropical spotted dolphin in the northern GOM is 91,321 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The pantropical spotted dolphin is the most abundant and commonly seen cetacean in deep waters of the northern GOM (Davis and Fargion, 1996; Jefferson, 1996; Mullin and Hansen, 1999; Davis et al., 2000; Würsig et al., 2000; Mullin et al., 2004). The Gulf of Mexico population is provisionally being considered a separate stock for management purposes, although there is no information that differentiates this stock from the Atlantic Ocean stock(s). This stock is not strategic, and the PBR for the northern Gulf of Mexico pantroical spotted dolphin is 293 (Waring et al., 2009).

Diving Behavior – Dives during the day generally are shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day (Baird et al., 2001). Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the eastern tropical Pacific and off Hawaii (Baird et al., 2001).

Acoustics and Hearing – Pantropical spotted dolphin whistles have a frequency range of 3.1 to 21.4 kHz (Thomson and Richardson, 1995). Clicks typically have two frequency peaks (bimodal) at 40 to 60 kHz and 120 to 140 kHz with estimated source levels up to 220 dB re 1 μPa peak-to-peak (Schotten et al., 2004). No direct measures of hearing ability are available for pantropical spotted dolphins, but ear anatomy has been studied and indicates that this species should be adapted to hear the lower range of ultrasonic frequencies (less than 100 kHz) (Ketten, 1992 and 1997).

Distribution – Pantropical spotted dolphins occur in subtropical and tropical waters worldwide (Perrin and Hohn, 1994). Pantropical spotted dolphins have been sighted along the Florida shelf and slope waters and offshore in Gulf Stream waters southeast of Cape Hatteras (Waring et al., 2007). Most sightings of this species in the GOM occur over the lower continental slope (Davis et al., 1998), although they are widely distributed in waters beyond the shelf edge.

Gulf of Mexico

Pantropical spotted dolphins are widely distributed in oceanic waters of the Gulf (Mullin and Fulling, 2004). Based on sighting survey data, this is the most commonly seen cetacean in deep waters of GOM.

In the winter, the pantropical spotted dolphin occurs in waters beyond the shelf break. Areas of increased occurrence are over a few areas of the Florida Escarpment, including the area the Tortugas Gyre influences, and over the slope off the Texas-Louisiana border.

Spring is the season with the most survey effort and a large number of sightings throughout the entire area of survey coverage. The pantropical spotted dolphin is predicted to occur in oceanic waters throughout the vast majority of the northern Gulf. There is an area of increased occurrence in waters over the abyssal plain south of the Mississippi Canyon region. There may be areas of greater occurrence also in the DeSoto Canyon region and over the Florida Escarpment.

In summer, occurrence is predicted in oceanic waters throughout the vast majority of the northern Gulf. There may be areas of increased occurrence west of the Mississippi Canyon region and in two areas over the Florida Escarpment.

Fall is the season with the least amount of recorded sightings, likely due to decreased survey effort during this season and inclement weather conditions that can make sighting cetaceans difficult during this time of year. Patchy occurrence is predicted seaward of the shelf break in waters over the continental slope. No seasonal shifts in occurrence for this species are known for this area.

Occurrence in the Study Area – Pantropical spotted dolphins are relatively common beyond the shelf break and are expected to occur in W-151. However, occurrence is much less likely in W-151A (the most frequently used portion of the range), which primarily occurs over the continental shelf.

Pygmy killer whale (*Feresa attenuata*)

Description – The pygmy killer whale is often confused with the melon-headed whale and less often with the false killer whale. Flipper shape is the best distinguishing characteristic; pygmy killer whales have rounded flipper tips (Jefferson et al., 1993). The body of the pygmy killer whale is somewhat slender (especially posterior to the dorsal fin) with a rounded head that has little or no beak (Jefferson et al., 1993). The color of this species is dark gray to black with a prominent narrow cape that dips only slightly below the dorsal fin and a white to light gray ventral band that widens around the genitals. The lips and snout tip are sometimes white. Pygmy killer whales reach lengths of up to 2.6 m (8.5 ft) (Jefferson et al., 1993).

Status - The best estimate of abundance for pygmy killer whales in the northern GOM is 408 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population is provisionally considered a separate stock for management purposes, although there is currently no information to distinguish this stock from Atlantic Ocean stock(s). The species is not strategic. PBR for the northern Gulf of Mexico pygmy killer whale is 2 animals.

Diving Behavior – There is no diving information available for this species.

Acoustics and Hearing – The pygmy killer whale emits short duration, broadband signals similar to a large number of other delphinid species (Madsen et al., 2004a). Clicks produced by pygmy killer whales have centroid frequencies between 70 and 85 kHz; there are bimodal peak frequencies between 45 and 117 kHz. The estimated source levels are between 197 and 223 dB re 1 µPa-m peak-to-peak (Madsen et al., 2004a). These clicks possess characteristics of echolocation clicks (Madsen et al., 2004a). There are no empirical hearing data available for this species.

Distribution – Pygmy killer whales have a worldwide distribution in tropical and subtropical waters, generally not ranging north of 40º N or south of 35º S (Jefferson et al., 1993). Most records from outside the tropics are associated with unseasonable intrusions of warm water into higher latitudes (Ross and Leatherwood, 1994). This species does not appear to be common in the GOM (Davis and Fargion, 1996; Jefferson and Schiro, 1997; Davis et al., 2000; Würsig et al., 2000). Würsig et al. (2000) suggested that the sparse number of sightings might be at least in part due to the somewhat cryptic behavior of the pygmy killer whale.

Gulf of Mexico

As stated previously, pygmy killer whales and melon-headed whales can be difficult to distinguish from one another, and on many occasions, only a determination of "pygmy killer whale/melon-headed whale" can be made. The occurrence of both species is considered similar and therefore appears combined. In the northern GOM, the pygmy killer whale is found primarily in deeper waters beyond the continental shelf (Davis and Fargion, 1996; Davis et al., 2000; Würsig et al., 2000) extending out to waters over the abyssal plain. Pygmy killer whales are thought to occur year-round in the Gulf in small numbers (Würsig et al., 2000). No seasonality to their occurrence is expected. The large number of sightings during the spring is due to high survey coverage during this time of year.

Occurrence in the Study Area – Encounters with pygmy killer whales during air-to-surface gunnery activities is considered unlikely due to the low number of sightings and deep water locations of sightings.

Risso's dolphin (*Grampus griseus*)

Description – Risso's dolphins are moderately large, robust animals reaching at least 3.8 m (12.5 ft) in length (Jefferson et al., 1993). The head is blunt and squarish without a distinct beak, and there is a vertical crease on the front of the melon. The dorsal fin is very tall and falcate. Young Risso's dolphins range from light gray to dark brownish gray and are relatively unmarked (Jefferson et al., 1993). Adults range from dark gray to nearly white and are heavily covered with white scratches and splotches.

Status – The best estimate of abundance for Risso's dolphins in the northern GOM is 2,169 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population is provisionally considered a separate stock. Currently there is little information to differentiate this stock from the Atlantic Ocean stock. This stock is not strategic, and the PBR for this species is 13 animals (Waring et al., 2009).

Diving Behavior – Individuals may remain submerged on dives for up to 30 minutes and dive as deep as 600 m (1,967 ft) (DiGiovanni et al., 2005).

Acoustics and Hearing – Risso's dolphin vocalizations include broadband clicks, barks, buzzes, grunts, chirps, whistles, and combined whistle and burst-pulse sounds that range in frequency from 0.4 to 22 kHz and in duration from less than a second to several seconds (Corkeron and Van Parijs, 2001). The combined whistle and burst pulse sound (2 to 22 kHz, mean duration of 8 seconds) appears to be unique to Risso's dolphin (Corkeron and Van Parijs, 2001). Risso's dolphins also produce echolocation clicks (40 to 70 µs duration) with a dominant frequency range of 50 to 65 kHz and estimated source levels up to 222 dB re 1 µPa-m peak-to-peak (Thomson and Richardson, 1995; Philips et al., 2003; Madsen et al., 2004b).

Baseline research on the hearing ability of this species was conducted by Nachtigall et al. (1995) in a natural setting (included natural background noise) using behavioral methods on one older individual. This individual could hear frequencies ranging from 1.6 to 100 kHz and was most sensitive between 8 and 64 kHz. Recently, the auditory brainstem response (ABR) technique has been used to measure hearing in a stranded infant (Nachtigall et al., 2005). This individual could hear frequencies ranging from 4 to 150 kHz, with best sensitivity at 90 kHz. This study demonstrated that this species can hear higher frequencies than previously reported.

Distribution – Risso's dolphins are distributed worldwide in cool-temperate to tropical waters from roughly 60º N to 60º S, where sea surface temperature (SST) is generally greater than 10º C (Kruse et al., 1999). In the western North Atlantic, this species is found from Newfoundland southward to the Gulf of Mexico, throughout the Caribbean, and around the equator (Würsig et al., 2000). In the GOM, Risso's dolphins occur year-round in the waters from the outer continental shelf seaward.

Gulf of Mexico

In general, Risso's dolphins occur year-round in the waters from the outer continental shelf seaward throughout the study area.

In the winter, Risso's dolphins are predicted to occur along the shelf break and over the continental slope. Interestingly, Mullin and Fulling (2004) found evidence of a three-fold increase in abundance in winter in the northeastern GOM compared to summer.

Spring is the season with the most survey effort and the largest (and most widespread) number of Risso's dolphin sightings. Risso's dolphins are predicted not only along the shelf break and continental slope but also over deeper waters of the abyssal plain. Three areas of concentration are off the DeSoto Canyon Region, off the Florida Escarpment, and in the region influenced by the Tortugas Gyre. These are all in areas of increased primary productivity, which would attract cephalopods, thereby attracting Risso's dolphins.

In the summer, Risso's dolphins may occur along the shelf break, over the continental slope, and over the abyssal plain. There may be a concentrated occurrence for Risso's dolphins in the region influenced by the Tortugas Gyre, which would be an area of increased biological productivity.

Fall is the season with the least amount of recorded sightings, likely due to decreased survey effort and inclement weather conditions that can make sighting cetaceans difficult during this time of year.

Occurrence in the Study Area – Risso's dolphins are likely to be encountered in W-151 seaward of the shelf break (i.e., 200-m isobath). Occurrence is not expected over the continental shelf, an area which comprises much of W-151A as shown in Figure 2-1.

Rough-toothed dolphin (*Steno bredanensis*)

Description – This is a relatively robust dolphin with a cone-shaped head; it is the only one with no demarcation between the melon and beak (Jefferson et al., 1993). The "forehead" slopes smoothly from the blowhole onto the long, narrow beak (Reeves et al., 2002). The rough-toothed dolphin has large flippers that are set far back on the sides and a prominent falcate dorsal fin (Jefferson et al., 1993). The body is dark gray with a prominent narrow dorsal cape that dips slightly down onto the side below the dorsal fin. The lips and much of the lower jaw are white, and many individuals have white scratches and spots on the body from cookie-cutter sharks and other rough-toothed dolphins. The rough-toothed dolphin reaches 2.8 m (9.2 ft) in length (Jefferson et al., 1993).

Status – The best estimate of abundance for rough-toothed dolphins in the northern GOM is 2,223 individuals (Fulling et al., 2003; Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population is provisionally considered a separate stock for management purposes, although there is currently no information to distinguish this stock from Atlantic Ocean stock(s). The species is not strategic. PBR for the northern Gulf of Mexico rough-toothed dolphin is 18 animals.

Diving Behavior –Rough-toothed dolphins may stay submerged for up to 15 minutes (Miyazaki and Perrin, 1994) and are known to dive as deep as 150 m (492 ft) (Manire and Wells, 2005).

Acoustics and Hearing – The rough-toothed dolphin produces a variety of sounds, including broadband echolocation clicks and whistles. Echolocation clicks (duration less than 250 microseconds [μsec]) typically have a frequency range of 0.1 to 200 kHz, with a dominant frequency of 25 kHz (Miyazaki and Perrin, 1994; Yu et al., 2003; Chou, 2005). Whistles (duration less than 1 sec) have a wide frequency range of 0.3 to greater than 24 kHz but dominate in the 2 to 14 kHz range (Miyazaki and Perrin, 1994; Yu et al., 2003).

AEP measurements were performed on six individuals involved in a mass stranding event on Hutchinson Island, Florida in August 2004 (Cook et al., 2005). The rough-toothed dolphin can detect sounds between 5 and 80 kHz and is most likely capable of detecting frequencies much higher than 80 kHz (Cook et al., 2005).

Distribution – Rough-toothed dolphins are found in tropical to warm-temperate waters globally, rarely ranging north of 40°N or south of 35°S (Miyazaki and Perrin, 1994). Rough-toothed dolphins occur in low densities throughout the eastern tropical Pacific where surface water temperatures are generally above 25° C (Perrin and Walker, 1975). This species is not a commonly encountered species in the areas where it is known to occur (Jefferson, 2002). Not many records for this species exist from the western North Atlantic, but they indicate that this species occurs from Virginia south to Florida, the Gulf of Mexico, the West Indies, and along the northeastern coast of South America (Leatherwood et al., 1976; Würsig et al., 2000). Two separate mass strandings of rough-toothed dolphins occurred in the Florida Panhandle during

December 1997 and 1998 (Rhinehart et al., 1999). Additionally, a mass stranding of a minimum of 70 individuals occurred off the Florida Keys on 2 March 2005 (Banick and Borger, 2005).

Gulf of Mexico

Rough-toothed dolphins occur in both oceanic and continental shelf waters in the northern Gulf of Mexico (Fulling et al., 2003; Mullin and Fulling, 2004). Rough-toothed dolphins were seen in all seasons during GulfCet aerial surveys of the northern Gulf of Mexico between 1992 and 1998 (Hansen et al., 1996; Mullin and Hoggard, 2000).

In the winter, there is only one sighting record available for this species during this season. Two stranded and rehabilitated individuals were released with tags in late March 1998 off Sarasota, Florida, and remained in the northeastern GOM (Wells et al., 1999). This is a time of year that is typically data deficient for deep water cetaceans in the Gulf because there is little survey effort. It is also the time when Beaufort sea states are highest which makes detection of species much more difficult (Mullin et al., 2004).

In the spring, rough-toothed dolphins occur in the deeper waters seaward of the shelf break, including over the abyssal plain. Sighting concentrations are predicted to be inshore of the Florida Escarpment and over the continental slope south of Louisiana.

In the summer, the greatest concentration of this species is suggested to be over the abyssal plain. Other concentrations are predicted on the west Florida Shelf and in the Mississippi Canyon region. This is the only time of the year that occurrence is also anticipated in continental shelf waters off southern Texas. The occurrence patterns for this season likely reflect the most realistic picture for the species since both oceanic and shelf occurrences are predicted.

In the fall, two sighting records are available for rough-toothed dolphins during this season. The predicted occurrence is in the Mississippi Canyon region. It should be noted that this is a time of year when Beaufort sea states are high which makes detection of species much more difficult (Mullin et al., 2004).

Occurrence in the Study Area – Encounters with rough-toothed dolphins during air-to-surface gunnery activities is not considered likely in any portion of W-151.

Short-finned pilot whale (*Globicephala macrorhynchus*)

Description – Pilot whales are among the largest dolphins, with short-finned pilot whales reaching lengths of 5.5 m (18.0 ft) (females) and 6.1 m (20.0 ft) (males) (Jefferson et al., 1993). Pilot whales have bulbous heads, with a forehead that sometimes overhangs the rostrum, and little or no beak. The falcate dorsal fin is distinctive; being generally longer than it is high, with a rounded tip and set well forward of the body's mid-length. Short-finned pilot whale flippers are sickle shaped. Pilot whales are black, with a light-gray saddle patch behind the dorsal fin in some individuals. There is also a white to light-gray anchor-shaped patch on the chest.

Status – The best estimate of abundance for the short-finned pilot whale in the northern GOM is 2,388 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population is provisionally considered a separate stock for management purposes, although there is currently no information to distinguish this stock from Atlantic Ocean stock(s). The species is not strategic. PBR for the northern Gulf of Mexico short-finned pilot whale is 5.4 animals.

Diving Behavior – Pilot whales are deep divers, staying submerged for up to 27 minutes and routinely diving to 600 to 800 m (1,967 to 2,625 ft) (Baird et al., 2003; Aguilar de Soto et al., 2005).

Acoustics and Hearing – Pilot whale sound production includes whistles and echolocation clicks. Short-finned pilot whale whistles and clicks have a dominant frequency range of 2 to 14 kHz and 30 to 60 kHz, respectively, at an estimated source level of 180 dB re 1 µPa-m peak-to-peak (Fish and Turl, 1976; Ketten, 1998).

There are no hearing data available for the short-fin pilot whale. However, the most sensitive hearing range for odontocetes generally includes high frequencies (Ketten, 1997).

Distribution – Short-finned pilot whales are found worldwide in warm-temperate and tropical offshore waters. Short-finned pilot whales are considered to be a tropical species that usually does not range north of 50º N or south of 40º S (Jefferson et al., 1993). However, strandings have been reported as far north as New Jersey (Payne and Heinemann, 1993). The short-finned pilot whale usually does not range north of 50°N or south of 40°S, however, short-finned pilot whales have stranded as far north as Rhode Island.

Gulf of Mexico

As noted by Jefferson and Schiro (1997), the identifications of many pilot whale specimen records in the GOM, and most or all sightings, have not been unequivocally shown to be of the short-finned pilot whale. Based on known distribution and habitat preferences of pilot whales, it is assumed that all of the pilot whale records in the northern GOM are of the short-finned pilot whale (Jefferson and Schiro, 1997; Würsig et al., 2000).

There is a preponderance of pilot whales in the historical records for the northern Gulf. Pilot whales, however, are less often reported during recent surveys, such as GulfCet (Jefferson and Schiro, 1997; Würsig et al., 2000). The reason for this apparent decline is not known, but Jefferson and Schiro (1997) suggested that abundance or distribution patterns might have changed over the past few decades, perhaps due to changes in available prey species which was noted off Catalina Island, California (Shane, 1994).

Mullin and Hansen (1999) noted that pilot whales are sighted almost exclusively west of the Mississippi River. There are a large number of historical strandings on the western coast of Florida and in the Florida Keys.

During the winter, there are no known seasonal changes in occurrence patterns for this species in the Gulf.

Spring is the season with the most survey effort. This species occurs in areas of steep bottom topography in most of the western Gulf, as well as in the region of the Mississippi River Delta and southwest of the Florida Keys.

In the summer, this species occurs in areas of steep bottom topography in most of the western Gulf, in the region of the Mississippi River Delta, and southwest of the Florida Keys. The pattern is similar in many respects to that predicted for spring, with some shifts in areas of concentration that might be indicative of temporal (yearly) differences in survey effort and sighting conditions.

In the fall, occurrence may be concentrated in locations around the shelf break, in particular, south of the Mississippi River Delta, over the continental slope. This is a time of a year with less survey effort than some other seasons (specifically spring and summer); therefore, it is possible that occurrence would be shown over a larger area if there was more survey effort during this time of year.

Occurrence in the Study Area – Based on sighting and stranding reports, which tend to be concentrated along the western Florida peninsula, Florida Keys, and Mississippi River delta, encounters with short-finned pilot whales in W-151 is considered unlikely.

Sperm whale (*Physeter macroceohalus*)

Description – The sperm whale is the largest toothed whale species. Adult females can reach 12 m (39 ft) in length, while adult males measure as much as 18 m (59 ft) in length (Jefferson et al., 1993). The head is large (comprising about one-third of the body length) and squarish. The lower jaw is narrow and underslung. The blowhole is located at the front of the head and is offset to the left (Rice, 1989). Sperm whales are brownish gray to black in color with white areas around the mouth and often on the belly. The flippers are relatively short, wide, and paddle-shaped. There is a low rounded dorsal hump and a series of bumps on the dorsal ridge of the tailstock (Rice, 1989). The surface of the body behind the head tends to be wrinkled (Rice, 1989).

Status – Sperm whales are classified as endangered under the ESA. The current best estimate of abundance for sperm whales in the northern GOM is 1,349 individuals (Mullin and Fulling, 2004). Based on mark-recapture analyses of photo-identified individuals, 398 individuals are suggested to utilize the region south of the Mississippi River Delta between the Mississippi Canyon and DeSoto Canyon along and about the 1,000-m (3,281-ft) isobath (Jochens et al., 2006). NMFS provisionally considers the sperm whale population in the northern GOM as a stock distinct from the U.S. Atlantic stock (Waring et al., 2006). Genetic analyses, coda vocalizations, and population structure support this (Jochens et al., 2006). This is a strategic stock because the species is listed as endangered under the ESA. PBR for the northern Gulf of Mexico sperm whale is 2.8. There is no designated critical habitat for this species.

Diving Behavior – Sperm whales forage during deep dives that routinely exceed a depth of 400 m (1,312 ft) and a duration of 30 minutes (Watkins et al., 2002). They are capable of diving to depths of over 2,000 m (6,562 ft) with durations of over 60 minutes (Watkins et al., 1993). Sperm whales spend up to 83 percent of daylight hours underwater (Jaquet et al., 2000; Amano and Yoshioka, 2003). Males do not spend extensive periods of time at the surface (Jaquet et al., 2000). In contrast, females spend prolonged periods of time at the surface (1 to 5 hours daily) without foraging (Whitehead and Weilgart, 1991; Amano and Yoshioka, 2003). An average dive cycle consists of about a 45 minute dive with a 9 minute surface interval (Watwood et al., 2006). The average swimming speed is estimated to be 0.7 meters per second (m/s) (1.4 knots[kn]) (Watkins et al., 2002). Dive descents for tagged individuals average 11 minutes at a rate of 1.52 m/sec (2.95 kn), and ascents average 11.8 minutes at a rate of 1.4 m/sec (2.7 kn) (Watkins et al., 2002).

Acoustics and Hearing – Sperm whales typically produce short-duration (less than 30 ms), repetitive broadband clicks used for communication and echolocation. These clicks range in frequency from 0.1 to 30 kHz, with dominant frequencies between the 2 to 4 kHz and 10 to 16 kHz ranges (Thomson and Richardson, 1995). When sperm whales are socializing, they tend to repeat series of group-distinctive clicks (codas), which follow a precise rhythm and may last for hours (Watkins and Schevill, 1977). Codas are shared between individuals of a social unit and are considered to be primarily for intragroup communication (Weilgart and Whitehead, 1997; Rendell and Whitehead, 2004). Recent research in the South Pacific suggests that in breeding areas the majority of codas are produced by mature females (Marcoux et al., 2006). Coda repertoires have also been found to vary geographically and are categorized as dialects, similar to those of killer whales (Weilgart and Whitehead, 1997; Pavan et al., 2000). For example, significant differences in coda repertoire have been observed between sperm whales in the Caribbean and those in the Pacific (Weilgart and Whitehead, 1997). Furthermore, the clicks of neonatal sperm whales are very different from those of adults. Neonatal clicks are of low-directionality, long-duration (2 to 12 ms), low-frequency (dominant frequencies around 0.5 kHz) with estimated source levels between 140 and 162 dB re 1 µPa-m rms, and are hypothesized to function in communication with adults (Madsen et al., 2003). Source levels from adult sperm whales' highly directional (possible echolocation), short (100 µs) clicks have been estimated up to 236 dB re 1 µPa-m rms (Møhl et al., 2003). Creaks (rapid sets of clicks) are heard most-frequently when sperm whales are engaged in foraging behavior in the deepest portion of their dives with intervals between clicks and source levels being altered during these behaviors (Miller et al., 2004; Laplanche et al., 2005). It has been shown that sperm whales may produce clicks during 81 percent of their dive period, specifically 64 percent of the time during their descent phases (Watwood et al., 2006).

The anatomy of the sperm whale's inner and middle ear indicates an ability to best hear high-frequency to ultrasonic frequency sounds. They may also possess better low-frequency hearing than other odontocetes, although not as low as many baleen whales (Ketten, 1992). The ABR technique used on a stranded neonatal sperm whale indicated it could hear sounds from 2.5 to 60 kHz with best sensitivity to frequencies between 5 and 20 kHz (Ridgway and Carder, 2001).

Distribution – Sperm whales are found from tropical to polar waters in all oceans of the world between approximately 70°N and 70°S (Rice, 1998). Females use a subset of the waters where males are regularly found. Females are normally restricted to areas with SST greater than approximately 15°C, whereas males, and especially the largest males, can be found in waters as far poleward as the pack ice with temperatures close to 0° (Rice, 1989). The thermal limits on female distribution correspond approximately to the 40° parallels (50° in the North Pacific; Whitehead, 2003).

The region of the Mississippi River Delta, which lies approximately 125 NM west of W-151, has been recognized for high densities of sperm whales and appears to represent an important calving and nursery area for these animals (Townsend, 1935; Collum and Fritts, 1985; Mullin et al., 1994; Würsig et al., 2000; Baumgartner et al., 2001; Davis et al., 2002; Mullin et al., 2004; Jochens et al., 2006). Body sizes for most of the sperm whales seen off the mouth of the Mississippi River range from 7 to 10 m (23 to 33 ft), which is the typical size for females and younger animals (Weller et al., 2000; Jochens et al., 2006). On the basis of photo-identification of sperm whale flukes and acoustic analyses, it is likely that some sperm whales are resident to the GOM (Weller et al., 2000; Jochens et al., 2006). Tagging data demonstrated that some individuals spend several months at a time in the Mississippi River Delta and the Mississippi Canyon for several months, while other individuals move to other locations the rest of the year (Jochens et al., 2006). Spatial segregation between the sexes was noted one year by Jochens et al. (2006); females and immatures showed high site fidelity to the region south of the Mississippi River Delta and Mississippi Canyon and in the western Gulf, while males were mainly found in the DeSoto Canyon and along the Florida slope.

Gulf of Mexico

Worldwide, sperm whales exhibit a strong affinity for deep waters beyond the continental shelf break (Rice, 1989). The recorded observations of sperm whales in the GOM support this trend, with sightings consistently recorded in waters beyond the 200-m (656-ft) isobath. Overall, sperm whales may occur year-round in the deepest waters of the northern GOM and the outer continental shelf waters in the region off the Mississippi River Delta, which may represent a significant calving and nursery area for the species in the northern GOM (Mullin et al., 2004). Sperm whales tend to be observed most often near the 1,000-m (3,281-ft) isobath (Jochens et al., 2006). They have been recorded (visually and acoustically) in sufficient numbers during all seasons to provide additional support to the belief that the Gulf of Mexico supports a resident population (Weller et al., 2000; Jochens et al., 2006). There is a consistent aggregation of sperm whales in the southeastern Gulf west of the Dry Tortugas (Mullin and Fulling, 2004). The Florida Straits represent a probable corridor for movements of individuals between the GOM and Caribbean Sea (or even western North Atlantic waters). These aggregations are thought to result from primary productivity associated with the Mississippi River plume and periodic formation of the cyclonic Tortugas Gyre near the Dry Tortugas.

In the winter, the occurrence of sperm whales is patchy, with all sighting records located in deep water. Survey effort during this season, especially in the deep waters of the Gulf, is low and may explain the paucity of sighting records. There may be a very small area of high concentration in deep waters over the Rio Grande Slope. Stranding records along western Florida and the Keys support the likelihood of sperm whale occurrence in waters off of Florida during this season.

During spring, there is the greatest intensity and distribution of survey effort which explains the large number of sightings during this time of year. The occurrence of sperm whales during this season is the most spatially extensive in the Gulf, with all sightings recorded in waters beyond the 200-m (656-ft) isobath. Sperm whales may occur in the deepest waters throughout the northern GOM and in all OPAREAs.

During summer, sperm whales may occur in the deepest Gulf waters west of the DeSoto Canyon, including the Corpus Christi, New Orleans, and Pensacola OPAREAs. There are stranding records in southern Florida, including the Florida Keys, as well as one sighting near the Florida Straits. Of interest is a report of a sperm whale giving birth on 15 July 2006, 88 NM (163 km) offshore of south Texas (no further details on the exact location were provided) (Christenson, 2006).

In the fall, occurrence records are relatively sparse and patchy in waters seaward of the shelf break. Whether the lower number of sighting records during this season is due to reduced survey effort or the movement of sperm whales out of the Gulf or into more southerly waters cannot be detailed without further seasonal survey effort.

Occurrence in the Study Area – Sperm whale occurrence in W-151A is unlikely, as almost all sightings have occurred in water depths greater than 200 meters. Occurrence in the deeper portions of W-151 is possible, although based on sighting locations, density is expected to be low.

Spinner dolphin (*Stenella longirostris*)

Description – The spinner dolphin has a very long, slender beak (Jefferson et al., 1993). The dorsal fin ranges from slightly falcate to triangular or even canted forward in some geographic forms. The spinner dolphin generally has a dark eye-to-flipper stripe and dark lips and beak tip (Jefferson et al., 1993). This species typically has a three-part color pattern (dark gray cape, light gray sides, and white belly). Adults can reach 2.4 m (7.9 ft) in length (Jefferson et al., 1993). There are four known subspecies of spinner dolphins and probably other undescribed ones (Perrin, 1998; Perrin et al., 1999).

Status – The best estimate of abundance for spinner dolphins in the northern GOM is 11,971 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population of spinner dolphins is provisionally being considered a separate stock for management purposes, but there is no information that differentiates this stock from Atlantic Ocean stock(s). This species is not a strategic stock. The PBR for the northern Gulf of Mexico spinner dolphin is 14 (Waring et al., 2009).

Diving Behavior – Spinner dolphins feed primarily on small mesopelagic fishes, squids, and sergestid shrimps, and they dive to at least 200 to 300 m (656 to 984 ft) (Perrin and Gilpatrick, 1994). Foraging takes place primarily at night when the mesopelagic community migrates vertically towards the surface and also horizontally towards the shore at night (Benoit-Bird et al., 2001; Benoit-Bird and Au, 2004). Rather than foraging offshore for the entire night, spinner dolphins track the horizontal migration of their prey (Benoit-Bird and Au, 2003). This tracking of the prey allows spinner dolphins to maximize their foraging time while foraging on the prey at its highest densities (Benoit-Bird and Au, 2003; Benoit-Bird, 2004).

Spinner dolphins are well known for their propensity to leap high into the air and spin before landing in the water; the purpose of this behavior is unknown. Norris and Dohl (1980) also described several other types of aerial behavior, including several other leap types, backslaps, headslaps, noseouts, tailslaps, and a behavior called "motorboating." Undoubtedly, spinner dolphins are one of the most aerially active of all dolphin species.

Acoustics and Hearing – Pulses, whistles, and clicks have been recorded from this species. Pulses and whistles have dominant frequency ranges of 5 to 60 kHz and 8 to 12 kHz, respectively (Ketten, 1998). Spinner dolphins consistently produce whistles with frequencies as high as 16.9 to 17.9 kHz with a maximum frequency for the fundamental component at 24.9 kHz (Bazúa-Durán and Au, 2002; Lammers et al., 2003). Clicks have a dominant frequency of 60 kHz (Ketten, 1998). The burst pulses are predominantly ultrasonic, often with little or no energy below 20 kHz (Lammers et al., 2003). Source levels between 195 and 222 dB re 1 μPa-m peak-to-peak have been recorded for spinner dolphin clicks (Schotten et al., 2004).

Distribution **–** Spinner dolphins are found in subtropical and tropical waters worldwide, with different geographical forms in various ocean basins. The range of this species extends to near 40° latitude (Jefferson et al., 1993). Spinner dolphins occur year-round in the deep waters of the GOM.

Gulf of Mexico

Spinner dolphins occur year-round in the deep waters of the GOM. Mullin and Fulling (2004) noted that the vast majority of spinner dolphin sightings made by NMFS-SEFSC were over the continental slope in the northeastern GOM. During the Fritts aerial surveys of the 1980s sightings were recorded in waters off southern Florida with a bottom depth of less than 200 m (656 ft) (Fritts et al., 1983). Based on the known habitat preferences of the spinner dolphin in the Gulf of Mexico, it is now thought that these animals were misidentified (Jefferson and Schiro, 1997; Würsig et al., 2000). It is probable that these dolphins were actually Atlantic spotted dolphins, based on known habitat preferences and distribution of this species.

In winter, spinner dolphins occur seaward of the shelf break including waters over the continental slope, primarily east of the Mississippi River, although also in the Mississippi Canyon region. The area of greatest occurrence is suggested to be southeast of DeSoto Canyon. It should be noted that this is a time of year when Beaufort sea states are highest, making detection much more difficult (Mullin et al., 2004).

During the spring, as in winter, spinner dolphins occur seaward of the shelf break including waters over the continental slope, primarily east of the Mississippi River, although also in the Mississippi Canyon region. The areas of greatest occurrence are likely to be in the DeSoto Canyon region, in waters over the Florida Escarpment, and in the area influenced by the Tortugas Gyre. It would be realistic to expect that this species is not relegated to central and eastern GOM and likely occurs throughout deep waters of the GOM, with the greatest likelihood of encountering this species being east of the Mississippi River.

In the summer, spinner dolphins may occur in the deeper waters of the north-central Gulf from the Mississippi Canyon to the Florida Panhandle. Increased occurrences of spinner dolphins may be found in the deeper waters just south of the Alabama slope.

In the fall, the presence of spinner dolphins in the GOM is recognized only based on sparse sighting and stranding data. The available sighting data places the species in the region of the Mississippi Canyon and DeSoto Canyon. Spring is the season that is most likely representative of what to expect for this species' occurrence, particularly since no seasonality for the species is known.

Occurrence in the Study Area – Spinner dolphins would likely be encountered in waters of W-151 seaward of the shelf break. As shown in Figure 2-1 only a small portion of W-151A consists of waters deeper than 200 m, therefore spinner dolphin occurrence in W-151A is considered unlikely.

Striped dolphin (*Stenella coeruleoalba*)

Description – The striped dolphin is uniquely marked with black lateral stripes from eye to flipper and eye to anus. There is also a white V-shaped "spinal blaze" originating above and behind the eye and narrowing to a point below and behind the dorsal fin (Leatherwood and Reeves, 1983). There is a dark cape and white belly. This is a relatively robust dolphin with a long, slender beak and prominent dorsal fin. This species reaches 2.6 m (8.5 ft) in length.

Status – The best estimate of abundance for striped dolphins in the northern GOM is 6,505 individuals (Mullin and Fulling, 2004; Waring et al., 2006). The Gulf of Mexico population of striped dolphins is provisionally being considered a separate stock for management purposes, but there is no information that differentiates this stock from the Atlantic Ocean stock(s). The PBR for the northern Gulf of Mexico striped dolphin is 23 and it is not considered a strategic stock (Waring et al., 2009).

Diving Behavior – Striped dolphins often feed in pelagic or benthopelagic zones along the continental slope or just beyond it in oceanic waters. A majority of their prey possess luminescent organs, suggesting that striped dolphins may be feeding at great depths, possibly diving to 200 to 700 m (656 to 2,297 ft) to reach potential prey (Archer II and Perrin, 1999). Striped dolphins may feed at night in order to take advantage of the deep scattering layer's diurnal vertical movements.

Acoustics and Hearing – Striped dolphin whistles range from 6 to greater than 24 kHz, with dominant frequencies ranging from 8 to 12.5 kHz (Thomson and Richardson, 1995). A single striped dolphin's hearing range, determined by using standard psycho-acoustic techniques, was from 0.5 to 160 kHz with best sensitivity at 64 kHz (Kastelein et al., 2003).

Distribution – Striped dolphins are distributed worldwide in cool-temperate to tropical zones. In the western North Atlantic, this species occurs from Nova Scotia southward to the Caribbean Sea, Gulf of Mexico, and Brazil (Würsig et al., 2000). Striped dolphins are usually found beyond the continental shelf, typically over the continental slope out to oceanic waters and are often associated with convergence zones and waters influenced by upwelling (Au and Perryman, 1985). As noted by Mullin and Hansen (1999), this species is generally distributed in deep waters throughout the entire northern GOM.

Gulf of Mexico

The striped dolphin is an oceanic species likely to occur seaward of the shelf break. As noted by Mullin and Hansen (1999), this species is generally distributed in deep waters throughout the entire northern GOM. During the Fritts aerial surveys of the early 1980s, striped dolphins were often recorded in shallow waters around southern Florida (Fritts et al., 1983). As noted earlier, striped dolphins have an apparent preference for deep waters. It is likely these sightings in waters over the continental shelf were misidentifications of Atlantic spotted dolphins (younger animals are not spotted and have a prominent spinal blaze like striped dolphins) (Jefferson and Schiro, 1997; Würsig et al., 2000).

In winter, striped dolphins are predicted to occur in waters over the continental slope, primarily in the central and eastern Gulf. Areas of greatest concentration are predicted for the Mississippi Canyon and DeSoto Canyon regions. This is a time of year with reduced survey effort, and it is more likely that occurrence is throughout the northern GOM seaward of the shelf break.

During spring, occurrence for the striped dolphins is predicted throughout the northern Gulf in waters over the continental slope and abyssal plain. The greatest concentration is in the DeSoto Canyon region, with an additional area over the abyssal plain. This is the season with the most survey effort and the largest (and most widespread) number of striped dolphin sightings.

In summer, occurrence is likely throughout the northern GOM near the shelf break and over the continental slope.

Fall is the season with the least amount of recorded sightings, likely due to decreased survey effort during this season and inclement weather conditions that can make sighting cetaceans difficult during this time of year. It is likely that the occurrence for the striped dolphin matches that in spring, and is predicted throughout the northern Gulf in waters over the continental slope and abyssal plain.

Occurrence in the Study Area – Striped dolphins would likely be encountered in waters of W-151 seaward of the shelf break. As shown in Figure 2-1 only a small portion of W-151A consists of waters deeper than 200 m, therefore striped dolphin occurrence in W-151A is considered unlikely.

5. TAKE AUTHORIZATION REQUESTED

A 1-year Incidental Harassment Authorization (IHA) is being requested until a 5-year Letter of Authorization (LOA) is issued for the incidental taking (but not intentional taking) of marine mammals. Take is requested for harassment only, including Level A and Level B (physiological and behavioral) harassment. The subsequent analyses in this request will identify the amount of applicable types of take. Mitigation measures, which are expected to substantially decrease the magnitude of potential impacts, are described in Section 11.

6. NUMBERS AND SPECIES TAKEN

Marine mammals may be potentially harassed due to noise from air-to-surface gunnery operations involving ordnance testing and training in the EGTTR. The potential numbers and species taken by noise are assessed in this section. Typical mission scenarios are described in Section 1. Three key sources of information are necessary for estimating potential noise effects on marine resources: 1) the zone of influence, which is the distance from the explosion to which a particular energy or pressure threshold extends; 2) the density of animals potentially occurring within the zone of influence; and 3) the number of distinct firing events.

Zone of Influence

The Zone of Influence (ZOI) is defined as the area of ocean in which marine mammals could potentially be exposed to various noise thresholds associated with exploding gunnery rounds. Marine mammals may potentially be affected by certain energy and pressure levels resulting from the exploding ordnance. Criteria and thresholds generally used for impact assessment in this document were originally developed for the shock trials of the *USS SEAWOLF* and *USS Winston S. Churchill* (DDG-81). An exception, explained later in this section, is the modification of the Level B harassment pressure metric associated with temporary threshold shift from 12 pounds per square inch (psi) to 23 psi. These thresholds are currently accepted and used by the NMFS for all similar underwater noise impact analyses. Criteria for assessing potential impacts include 1) injury (hearing-related and non-hearing related) and 2) harassment (temporary loss of some hearing ability and behavioral reactions). Due to the small amounts of net explosive weight for each of the rounds fired in the EGTTR and the mitigation measures proposed for implementation, mortality resulting from detonations in the water column is considered highly unlikely and is not evaluated further by Eglin AFB or NMFS. Eglin has determined that an annual total of only 0.01 cetaceans (all species combined), in the absence of mitigation measures, could be exposed to pressure levels associated with mortality. Refer to the 2009 Notice of Proposed IHA (74 FR 53474, October 19, 2009) for the NMFS' determination that such lethal impacts are highly unlikely. The paragraphs below provide a general discussion of the various criteria, metrics, and thresholds used for impact assessment.

Metrics

Standard impulsive and acoustic metrics were used for the analysis of underwater energy and pressure waves in this document. Four metrics are particularly important for this risk assessment.

- *Peak Pressure*: This is the maximum positive pressure, or peak amplitude of impulsive sources, for an arrival. Units are psi and decibel levels with the usual underwater reference of 1 μPa.

- *Positive Impulse*: This is the time integral of the pressure over the initial positive phase of an arrival. This metric represents a time-averaged pressure disturbance from an explosive source. Units are typically Pascal-second (Pa-s) or pounds per square inch per millisecond (psi-msec). The latter is used in this document. There is no decibel analog for impulse.
- *Energy flux density (EFD)*: For plane waves, which is assumed for acoustic energy produced by the actions described in this document, EFD is the time integral of the squared pressure divided by the impedance. EFD levels have units of Joules per square meter (J/m^2), inch-pounds per square inch ($in\text{-}lb/in^2$), or decibels referenced to one squared microPascal-second (dB re 1 μPa^2-s) (with the usual convention that the reference impedance is the same as the impedance at the field point). The latter unit is used in this document.
- *1/3-Octave EFD*: This is the EFD in a 1/3-octave frequency band. A 1/3-octave band has upper and lower frequency limits with a ratio of $2^{1/3}$. Therefore, the band width is approximately 25 percent above and below center frequency. The 1/3 octave selected is the hearing range at which the subject animals' hearing is believed to be most sensitive.

Criteria and Thresholds: Mortality

Lethal impacts are associated with exposure to a certain level of positive impulse pressure, expressed as psi-msec. The criterion for marine mammal mortality used in the *Churchill* document is "onset of severe lung injury." The threshold is stated in terms of the Goertner (1982) modified positive impulse with value indexed to 30.5 psi-msec. The Goertner approach depends on propagation, source/animal depths, and animal mass in a complex way. Since animals of greater mass can withstand greater pressure shock waves, this threshold was conservatively based on the mass of a dolphin calf. This threshold is further conservative in that, although it corresponds to only a one percent chance of mortal injury, any animal experiencing onset of severe lung injury is considered to be lethally taken. Air-to-surface gunnery activities are not expected to cause mortality for any cetacean species.

Criteria and Thresholds: Injury (Level A Harassment)

Non-lethal injurious impacts are currently defined with dual criteria: 1) eardrum (i.e., tympanic-membrane [TM]) rupture, and 2) the onset of slight lung injury. These criteria are considered indicative of the onset of injury. The more conservative (i.e., most impactive) of the two thresholds are typically used for effects analysis as a conservation measure. The threshold for TM rupture is considered to correspond to a 50 percent rupture rate (i.e., 50 percent of animals exposed to the threshold are expected to suffer TM rupture). This threshold is considered to be an EFD value of 1.17 $in\text{-}lb/in^2$, which corresponds to approximately 205 dB re 1 μPa^2-s (the term "sound exposure level" is increasingly used synonymously with EFD). TM rupture is not necessarily considered a life-threatening injury, but is a useful index of possible injury that is well-correlated with measures of permanent hearing impairment (e.g., Ketten (1998) indicates a 30 percent incidence of permanent threshold shift (PTS) at this threshold).

The onset of slight lung injury is the second criterion considered indicative of non-lethal injury. A cetacean would be expected to recover from this type of injury. The criterion is associated with a positive impulse level which is given in terms of the Goertner (1982) modified positive impulse metric indexed to 13 psi-msec. The 13 psi-msec threshold corresponds to slight lung injury in a dolphin calf. The impact range for similar injury in an adult dolphin or larger cetacean would be less. Again, as a conservative measure, the 13 psi-msec threshold is used to estimate impacts to all cetaceans.

Criteria and Thresholds: Non-Injurious Impacts (Level B Harassment)

Public Law 108-136 (2004) amended the definition of Level B harassment under the MMPA for military readiness activities. For such activities, Level B harassment is defined as "any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioral patterns including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering to a point where such behavioral patterns are abandoned or significantly altered." Thus, Level B harassment is limited to non-injurious impacts. Unlike Level A harassment, which is solely associated with physiological effects, both physiological and behavioral effects may be considered Level B harassment.

The physiological effect associated with non-injurious Level B harassment is known as TTS, which is defined as a temporary, recoverable loss of hearing sensitivity (NMFS, 2001; DON, 2001). Two criteria are considered indicative of the onset of TTS. The first criterion is an SEL of 182 dB re 1 μPa^2-s maximum EFD level in any 1/3-octave band at frequencies above 0.1 kHz for toothed whales and in any 1/3-octave band above 0.010 kHz for baleen whales. The second criterion is stated in terms of peak pressure at 23 psi. This threshold is derived from the CHURCHILL document and was subsequently adopted by NMFS in its Final Rule on the unintentional taking of marine animals incidental to the shock testing (NMFS, 2001). The original criteria incorporated 12 psi. The current criteria and threshold for peak pressure over all exposures was updated from 12 psi to 23 psi for explosives less than 907 kg (2,000 lb) based on an IHA issued to the Air Force for a similar action (NOAA, 2006). Peak pressure and energy scale at different rates with charge weight, so that ranges based on the peak-pressure threshold are much greater than those for the energy metric when charge weights are small, even when source and animal are away from the surface. In order to more accurately estimate TTS for smaller detonations while preserving the safety feature provided by the peak pressure threshold, the threshold is appropriately scaled for small shot detonations. This scaling is based on the similitude formulas (e.g., Urick, 1983) used in virtually all compliance documents for short ranges. Further, the peak-pressure threshold for TTS due to explosives offers a safety margin for source or animal near the ocean surface. The more conservative (i.e., larger) range of the two criteria is used to estimate impacts to marine mammals in this document.

Behavioral reactions may occur at noise levels below those considered to cause TTS in marine mammals, particularly in cases of multiple detonations. Behavioral effects may include decreased ability to feed, communicate, migrate, or reproduce, among others. Such effects are known as sub-TTS Level B harassment. Behavioral effects are currently considered to occur at an EFD level of 177 dB re 1 μPa^2-s.

Table 6-1 provides a summary of criteria and thresholds used in this document for potential noise impacts to marine mammals. Table 6-2 provides the estimated range from the detonation point to which the various thresholds extend. This range, or radius, is then used to calculate the total area affected by a gunnery round. Threshold ranges were calculated for two seasons (summer and winter) and depth strata (80 m and 160 m) in order to reasonably bound the environmental conditions in which gunnery activities may occur. As a conservation measure, the greatest range within each season and depth strata are used in take estimate calculations. Further, where dual criteria exist, the criterion resulting in the most conservative estimate (i.e., largest amount of take) is used. See APPENDIX A for a detailed explanation on how the ranges were calculated for the criteria and thresholds used in this analysis.

Although dual criteria have been developed for Level A and Level B (physiological) harassment, a dual criterion has not been adopted by NMFS for non-TTS behavioral responses by marine mammals due to lack of empirical information and data. Therefore, while it would generally be expected that the threshold for behavioral modification would be lower than that causing TTS, the impact area for physiological effects used for take estimates may in some cases be greater than that associated with behavioral effects.

Table 6-1. Criteria and Thresholds Used for Impact Analyses

Mortality	Level A Harassment		Level B Harassment		
30.5 psi-msec	**205 dB re 1 μPa^2-s EFD***	**13 psi-msec**	**182 dB re 1 μPa^2-s EFD***	**23 psi peak pressure**	**177 dB re 1 μPa^2-s EFD***
Onset of severe lung injury	TM rupture in 50% of exposed animals	Onset of slight lung injury	TTS	TTS	Behavioral response

*In greatest 1/3-octave band above 10 Hz or 100 Hz

Table 6-2. Estimated Threshold Radii (meters) for Air-To-Surface Gunnery Ordnance

Ordnance Type	Mortality	Level A Harassment		Level B Harassment		
	30.5 psi-msec (m)	**205 dB EFD* (m)**	**13 psi-msec (m)**	**182 dB EFD* (m)**	**23 psi (m)**	**177 dB EFD* (m)**
105 mm FU	3.8	22.81	6.96	158.26	216.37	281.78
105 mm TR	2.45	8.86	3.29	49.79	91.45	90.46
40 mm	3.07	12.52	3.69	74.27	123.83	142.11
25 mm	1.26	0	2.52	23.83	52.72	41.24

FU = Full Up Round
TR = Training Round
* In greatest 1/3-octave band above 10 Hz or 100 Hz

Marine Mammal Density

Density estimates for marine mammals occurring in the EGTTR are provided in Table 3-1. As discussed in Chapter 3, densities were derived from the NODE document, and were determined by either model-derived estimates or literature-derived estimates. In order to address potential negative bias in the underlying survey results, Eglin AFB has adjusted density estimates by use of submergence factors.

Number of Events

Appropriate calculation of the number of distinct firing events from gunnery missions is necessary to perform noise analyses. The method of deriving the number of firing events may differ for energy and pressure metrics. For energy metrics, the number of firing events is synonymous with the quantity of rounds expended, as energy is proportional to the total charge weight. When utilizing energy threshold metrics, the energy released from multiple shots should be evaluated as an additive exposure and, therefore, events must consider all shots fired.

Conversely, it is not appropriate to consider pressure as additive when multiple explosions occur simultaneously or over a very short time frame, and an alternative method for estimating the number of events for use in take calculations is necessary. Typically, pressure-based thresholds are based on the maximum value received by an animal. The standard load for105 mm ordnance is 30 rounds per mission. The 105 mm rounds are fired singly as separate rounds, with up to 30-second intervals between rounds, resulting in approximately two rounds per minute expended. As a conservative scenario, Eglin assumes that one marine mammal is present within or near the 282-m 177 dB EFD Level B behavioral harassment ZOI, which is the largest ZOI evaluated in this document, when firing begins. The overall marine mammal density determination (Table 3-1) assumes a uniform distribution of approximately 1.4 animals per km^2, which results in a distance of approximately 843 m between each animal (all species) on average. The average cetacean swim speed is assumed to be 3 knots, or 1.5 m/s. At this density distribution and swim speed, and assuming a straight-line, continuous swim profile in the direction of gunnery activities, the next available cetacean would approach the perimeter of the 216-m ZOI in approximately 9.4 minutes. With 105 mm live-fire events occurring at a rate of about 2 per minute, approximately 18 to 19 rounds of the thirty-round load (or approximately two-thirds of the total load) would be expended within the 9.4 minute time frame. Based on this scenario, one cetacean would be present in the ZOI at the beginning of live fire, and an additional cetacean would enter the ZOI after 9.4 minutes. The remaining 11 to 12 rounds would be expended in approximately 6 minutes, which would not be enough time for an additional animal to enter the ZOI. However, allowing for potential pauses in firing, it may be assumed that one additional animal would enter the ZOI, so that up to three cetaceans could be exposed to the 23 psi TTS threshold associated with 105 mm Full Up ordnance during a typical mission. Therefore, one cetacean would be within the ZOI for every 10 rounds fired (30 divided by 3), on average. The number of rounds required to result in one exposure is considered an event. Therefore, the total number of rounds fired per year is divided by 10. It should be noted that this scenario does not take into account the possibility of marine mammals avoiding the area once firing begins.

The method for estimating the number of firing events for 40 mm and 25 mm rounds, as they relate to pressure metrics, is more straightforward. These rounds are typically fired in bursts, with each burst expended within a 2- to 10-second time frame. Given the average cetacean density and swim speed (see discussion in the previous paragraph), there would not be sufficient time for new animals to enter the ZOI within the time frame of a single burst. As such, only the peak pressure of a single round per burst is experienced within a given ZOI. For 40 mm rounds, a typical mission includes 64 rounds, with approximately 20 rounds per burst. Based on the very tight target area and extremely small “miss” distance, all rounds in a burst are expected to enter the water within 5 meters of the target. Therefore, take calculations in this document are based on the total number of rounds fired per year divided by 20. Similarly, for 25 mm rounds, missions typically entail 560 rounds fired in bursts of 100 rounds, and take calculations are based on the total number of rounds divided by 100.

Using the adjusted density estimates of each species, the ZOI of each type of round deployed, and the total number of events per year, an annual estimate of the potential number of animal takes from noise can be calculated. Table 6-3 provides the total number of potentially affected (exposed) marine mammals for all combined gunnery events, including105-mm (FU and TR), 40-mm, and 25-mm rounds. The numbers in Table 6-3 represent the maximum number of exposures considered reasonably possible. It should be noted that these exposure estimates are derived without consideration of mitigation measures (except use of the 105-mm TR), which are presented in Chapter 11. For Level A harassment calculations, the ZOI corresponding to 205 dB EFD is used because this criterion results in the most conservative take estimate. Similarly, for Level B physiological harassment calculations, the ZOI corresponding to the 182 dB EFD threshold is used because this criterion results in the most conservative take estimate even though the 23 psi threshold radii are greater than the radii corresponding to the 182 dB SEL threshold.

Table 6-3. Yearly Number of Marine Mammals Potentially Affected by the Gunnery Mission Noise

Species	Adjusted Density (#/km^2)	Mortality 30.5 psi-msec	Level A Harassment		Level B Harassment (TTS)		Level B Harassment Non-Injurious 176 dB* EFD For Behavior
			Injurious 205 dB* EFD	Injurious 13 psi-msec	Non-Injurious 182 dB* EFD	Non-Injurious 23 psi Peak Pressure	
Bryde's whale	0.000175	0.00000003	0.000007	0.000000	0.00041	0.00005	0.00137
Sperm whale	0.003345	0.00000060	0.000130	0.000001	0.00783	0.00094	0.02617
Dwarf/pygmy sperm whale	0.001905	0.00002725	0.007019	0.000062	0.40696	0.05371	1.33528
All beaked whales	0.000013	0.00000000	0.000001	0.000000	0.00003	0.00000	0.00010
Killer whale	0.000387	0.00000007	0.000015	0.000000	0.00091	0.00011	0.00303
Pygmy killer whale	0.001189	0.00000021	0.000046	0.000000	0.00278	0.00034	0.00930
False killer whale	0.003023	0.00000054	0.000118	0.000001	0.00708	0.00085	0.02365
Melon-headed whale	0.010050	0.00000180	0.000391	0.000004	0.02353	0.00283	0.07863
Short-finned pilot whale	0.006857	0.00000123	0.000267	0.000002	0.01606	0.00193	0.05365
Rough-toothed dolphin	0.001295	0.00000023	0.000050	0.000000	0.00303	0.00037	0.01013
Bottlenose dolphin	0.631900	0.00903926	2.328211	0.020735	134.99056	17.81699	442.92035
Risso's dolphin	0.012107	0.00000217	0.000471	0.000004	0.02835	0.00341	0.09472
Atlantic spotted dolphin	0.352333	0.00504008	1.298157	0.011561	75.26765	9.93434	246.96226
Pantropical spotted dolphin	0.142900	0.00002562	0.005561	0.000050	0.33464	0.04028	11.11803
Striped dolphin	0.030907	0.00000554	0.001203	0.000011	0.07238	0.00871	0.24181
Spinner dolphin	0.127000	0.00002277	0.004942	0.000045	0.29740	0.03580	0.99363
Clymene dolphin	0.050533	0.00000906	0.001966	0.000018	0.11833	0.01424	0.39536
Fraser's dolphin	0.002115	0.00000038	0.000082	0.000000	0.00495	0.00060	0.01655
All marine mammals	1.378034	0.01417684	3.648637	0.032496	211.58290	27.91551	694.28402

km^2 = square kilometers; NA = not applicable
*dB= dB re 1 μPa^2-s
**Bottlenose dolphin/Atlantic spotted dolphin

7. IMPACTS TO MARINE MAMMAL SPECIES OR STOCKS

The numbers of marine mammals potentially impacted by air-to-surface gunnery activities are based on impulsive noise generated by ordnance detonation at or near the water surface. Impacts may result from energy or pressure associated with the detonations. Exposure to these metrics could result in injury or harassment of marine mammal species. A maximum of 70 gunnery missions annually are analyzed on this document, which averages one mission approximately every five days. Live fire persists for approximately 30 minutes per mission, which would result in a maximum of one-half hour of noise-producing activities every five days occurring at a discreet, variable location within the 10,000 NM^2 area of W-151 (although most activities are expected to occur within the 2,500 NM^2 area of W-151A).

Based on the analyses and results provided in Section 6, a total of approximately four marine mammals could potentially be exposed (annually) to injurious Level A harassment associated with the 205 dB EFD threshold. Take associated with this criterion is considered to correspond to TM rupture in 50 percent of animals exposed, which corresponds to 30 percent PTS. It is expected that TM rupture, while not necessarily life–threatening, could decrease the ability of individual animals to detect prey and predators and to receive auditory cues from conspecifics. It should be noted that calculations resulted in only small fractions of an animal taken for most species. Species for which takes are calculated at one-half an animal or greater include Atlantic bottlenose dolphin (2.3 animals) and Atlantic spotted dolphin (1.3 animals).

Approximately 212 marine mammals could potentially be exposed to non-injurious (TTS) Level B harassment associated with the 182 dB EFD threshold. TTS results from fatigue or damage to hair cells or supporting structures and may cause disruption in the processing of acoustic cues. However, hearing sensitivity is recovered within a relatively short time. As with takes for Level A harassment, only a fraction of an animal is calculated for most species. Species for which takes are calculated at one-half an animal or greater include Atlantic bottlenose dolphin (135 animals) and Atlantic spotted dolphin (75 animals).

Approximately 694 animals could potentially be exposed to noise corresponding to the behavioral threshold of 177 dB EFD. Behavioral harassment occurs at distances beyond the range of structural damage and hearing threshold shift. Possible behavioral responses to a detonation include panic, startle, departure from an area, and disruption of activities such as feeding or breeding.

The marine mammal species potentially affected are generally not considered strategic stocks, with the exception of sperm whales and five bottlenose dolphin stocks. The sperm whale is considered a strategic stock because it is listed as endangered under the ESA. The likelihood of impacting this species is considered low because much of W-151 (and in particular W-151A; see Figure 1-3) is located on shallower portions of the continental shelf where sperm whale occurrence is low. Also, it is expected that sperm whales at or near the surface would be observed during the required pre-mission visual surveys described in Chapter 11. It is acknowledged, however, that sperm whales could occur in the deeper offshore portions of W-151 over the shelf break. Bottlenose dolphins from five bay, sound, and estuarine stocks, which are designated as strategic, could be affected by gunnery activities. It is not probable that large numbers of dolphins from these stocks would be affected, given that gunnery missions generally occur more than 15 miles off shore. However, individuals from these stocks may move into deeper water at times, and therefore potentially occur in areas used for gunnery missions. It is expected that mitigation measures, described in Section 11, will substantially reduce the number of animals impacted.

8. IMPACT ON SUBSISTENCE USE

Potential impacts resulting from the proposed activity will be limited to individuals of marine mammal species located in the Gulf of Mexico that have no subsistence requirements. Therefore, no impacts on the availability of species or stocks for subsistence use are considered.

9. IMPACTS TO MARINE MAMMAL HABITAT AND THE LIKELIHOOD OF RESTORATION

The primary source of marine mammal habitat impact is noise resulting from gunnery missions. However, the noise does not constitute a long-term physical alteration of the water column or bottom topography, as the occurrences are of limited duration and are intermittent in time. The target flare's burn time normally lasts 10 to 20 minutes. Given this short time of a lighted environment and the variable locations they are dropped, no increases in density of phytoplankton or other organisms considered to be primary producers would affect marine mammal habitat or populations. Also, live fires are a continuous event with pauses during the firing usually well under a minute and rarely from 2 to 5 minutes. Likewise, surface vessels associated with the missions are present in limited duration and are intermittent as well. Therefore, it is not anticipated that marine mammals will stop utilizing the waters of W-151, either temporarily or permanently, as a result of air-to-surface gunnery activities.

Other sources that may affect marine mammal habitat were considered and potentially include the introduction of fuel, chaff, debris, ordnance, and chemical residues into the water column. Chemical residues can enter the water through ammunition, flares, drones, missiles, and smoke. The effects of each of these components were considered in the EGTTR PEA and were determined to be insignificant (U.S. Air Force, 2002). Concentrations of chemical residues that could be added to the water during ordnance testing such as carbon dioxide, carbon monoxide, nitrogen dioxide, nitrogen oxides, and RDX were determined to be negligible amounts (0.03 μg/L and lower depending on the compound). These small amounts would be quickly diluted through wave action, currents, and tides, resulting in minimal to no impacts to the marine mammal habitat. The tendency for marine mammals to avoid regions of reduced water quality, particularly waters having reduced visibility (Dohl et al., 1983), lessens the opportunity for direct exposure. Please refer to pages 4-1 through 4-33 in the EGTTR PEA for a more detailed analysis of Eglin's programmatic mission activities other than noise-related air-to-surface gunnery activities.

10. IMPACTS TO MARINE MAMMALS FROM LOSS OR MODIFICATION OF HABITAT

Based on the discussions in Section 9, marine mammal habitat will not be lost or modified.

11. MEANS OF AFFECTING THE LEAST PRACTICABLE ADVERSE IMPACTS

The potential takes outlined in Section 6 represent the maximum expected number of animals that could be exposed to take thresholds. None of the impact estimates take into consideration measures that will be employed by the proponent to minimize impacts to protected species. Eglin AFB has employed a number of mitigation measures, which are discussed below, in an effort to substantially decrease the number of animals potentially affected. Eglin AFB is committed to assessing the mission activity for opportunities to provide operational mitigations (i.e. ramping up and using nighttime training rounds) while potentially sacrificing some mission flexibility. The principle functional mitigation measure consists of visual observation. Use of the 105 mm Training Round and ramp-up procedures are also included.

Visual Monitoring

Areas to be used in gunnery missions are visually monitored for marine mammal presence from aircraft prior to commencement of the mission. If the presence of marine mammals is detected, the target area will be avoided. In addition, monitoring will continue during the mission. If marine mammals are detected at any time, the mission will halt immediately and relocate as necessary or be suspended until the marine mammal has left the area. Visual monitoring will be supplemented with IR and low-light television (TV) monitoring. A detailed description of visual monitoring is provided below.

Pre-Mission and Mission Monitoring

AC-130 gunships travel to potential mission locations outside U.S. territorial waters (typically about 15 NM from shore) at an altitude of approximately 6,000 feet (1,829 m). Such a location places most mission activities over shallower continental shelf waters where marine mammal densities are typically lower, and thus potentially avoids the slope waters where more sensitive species (e.g., endangered sperm whales) generally reside. After arriving at the target site, and prior to initiating firing events, the aircraft crew will conduct a visual and instrument survey of the 5-NM (9.3 km) prospective target area in order to verify the presence/absence of surface vessels, protected marine species or indicators, and other objects that would render the site unsuitable. The gunship will conduct at least two complete orbits at a minimum safe airspeed around the prospective site at the 6,000 foot altitude. Provided that marine mammals (and other protected species or indicators) are not detected, the AC-130 will then begin the ascent to mission altitude, continuing to orbit the target area as it climbs. The initial orbits occur over a time frame of 15 minutes. Monitoring for marine mammals, vessels, and other objects will continue throughout the mission.

During the low altitude orbits and climb, the aircraft crew will visually scan the sea surface within the aircraft's orbit circle for the presence of marine mammals. Primary emphasis for the surface scan will be upon the flight crew in the cockpit and personnel stationed in the tail observer bubble and starboard viewing window. During nighttime missions, crews will use night vision goggles during observation. In addition to visual surveys, the AC-130's optical and electronic sensors will also be used for site clearance. AC-130 gunships are equipped with low-light TV cameras and AN/AAQ-26 Infrared Detection Sets (IDS). The TV cameras operate in a range of visible and near-visible light. Infrared systems are capable of detecting differences in temperature from thermal energy (heat) radiated from living bodies, or from reflected and scattered thermal energy. In contrast to typical night-vision devices, visible light is not necessary for object detection. IR systems are equally effective during day or night use. The IDS is capable of detecting very small thermal differences. See the Notice of IHA (73 FR 246, December 22, 2008) for a further description of AC-130 sensor capabilities.

If any marine mammals are detected during pre-mission surveys or during the mission, activities will be immediately halted until the area is clear of all marine mammals for 60 minutes, or the mission will be relocated to another target area. If the mission is relocated, the survey procedures will be repeated. In addition, if multiple firing missions are conducted within the same flight, clearance procedures will precede each flight.

Post-Mission Monitoring

Aircraft crews will conduct a post-mission survey beginning at the operational altitude of approximately 15,000 to 20,000 feet elevation and proceeding through a spiraling descent to approximately 6,000 feet. It is anticipated that the descent will occur over a three- to five-minute time period. During this time, aircrews will use the IDS and low-light TV systems to scan the water surface for animals that may have been impacted during the gunnery exercise. During daytime missions, visual scans will be used as well. If post-mission surveys determine that an injury or lethal take of a marine mammal has occurred, the test procedure and the monitoring methods must be reviewed with NMFS, and appropriate changes made as necessary prior to conducting the next gunnery exercise.

Sea State Restrictions

If daytime weather and/or sea conditions preclude adequate aerial surveillance for detecting marine mammals and other marine life, air-to-surface gunnery exercises will be delayed until adequate sea conditions exist for aerial surveillance to be undertaken. Daytime live fire will be conducted only when sea surface conditions are sea state of 4 or less on the Beaufort scale.

Development and Use of Training Round

The largest type of ammunition used during typical gunnery missions is a 105-mm round, which contains 4.7 pounds of high explosive (HE). This is several times more HE than that found in the next largest round (40 mm). As a mitigation technique, the Air Force developed a 105-mm training round that contains only 0.35 pounds of HE. The training round was developed to substantially reduce the risk of harassment during nighttime operations, when visual surveying for marine mammals is of limited effectiveness (monitoring by use of the AC-130's instrumentation, however, as described in the Visual Monitoring section above, is effective at night). An example of the expected effectiveness of this mitigation is presented in Table 11-1. The conservative threshold level of 160 dB re 1 μPa^2-s is used here to better show the difference in the size of the ZOI and the number of animals exposed between the training round and the full-up round.

Table 11-1. Example of Mitigation Effectiveness Using the 105-mm Training Round Versus the 105-mm Full Up Round

Threshold (dB)	105 mm TR (~0.3 lbs. HE)		105 mm FU (~4.7 lbs. HE)		Mitigation (Percent Reduction)	
	ZOI (km^2)	Affected Animals (#)	ZOI (km^2)	Affected Animals (#)	ZOI (%)	Affected Animals (%)
160	6.8	40.9	179.2	1,078.8	96	96

TR = training round; HE = high explosive; km2 = square kilometers

Ramp-Up and Warning Procedures

Ramp-up procedures refer to the process of beginning with the least impactive action and proceeding to subsequently more impactive actions. In the case of air-to-surface gunnery activities, ramp-up procedures entail beginning a mission with the lowest caliber munition and proceeding to the highest, which means the munitions would be fired in the order of 25 mm, 40 mm, and 105 mm. The rationale for the procedure is that this process may allow marine species to perceive steadily increasing noise levels and to react, if necessary, before the noise reaches a threshold of significance.

The AC-130 gunship's weapons are used in two phases. First, the guns are checked for functionality and calibrated. This step requires an abbreviated period of live fire. After the guns are determined to be ready for use, the mission proceeds under various test and training scenarios. This second phase involves a more extended period of live fire and can incorporate use of one or any combination of the munitions available (25mm, 40mm, and 105 mm rounds).

The ramp-up procedure will be required for the initial calibration phase and, after this phase, the guns may be fired in any order. Eglin AFB believes this process will allow marine species the opportunity to respond to increasing noise levels. If an animal leaves the area during ramp-up, it is unlikely to return while the live-fire mission is proceeding. This protocol allows a more realistic training experience. In combat situations, gunship crews would not necessarily fire the complete ammunition load of a given caliber gun before proceeding to another gun. Rather, a combination of guns would likely be used as required by an evolving situation. An additional benefit of this protocol is that mechanical or ammunition problems on an individual gun can be resolved while live fire continues with functioning weapons. This diminishes the possibility of a lengthy pause in live fire which, if greater than 10 minutes, would necessitate re-initiation of protected species surveys.

12. MINIMIZATION OF ADVERSE EFFECTS ON SUBSISTENCE USE

Based on the discussions in Section 8, there are no impacts on the availability of species or stocks for subsistence use.

13. MONITORING AND REPORTING MEASURES

For air-to-surface gunnery activities, including daytime and nighttime missions, areas to be used will be monitored for marine mammal presence prior to commencement of the mission. Monitoring will continue throughout the mission, and a post-mission survey will be carried out. Monitoring will be conducted using visual scans and the AC-130's instrumentation, including the IDS and low-light TV systems. If any marine mammals are detected during pre-mission surveys or during the mission, activities will be immediately halted until the area is clear of all marine mammals, or the mission will be relocated to another area. Refer to Chapter 11 for a more detailed explanation of monitoring requirements.

In addition to monitoring for marine species before, during, and after gunnery missions, the following monitoring and reporting measures will be required.

- The air-to-surface gunnery mission aircrews will participate in marine mammal observation training. Each crew member will be required to complete the training prior to participating in a gunnery mission. The training will include protected species survey and identification techniques.
- Eglin AFB will track use of the EGTTR for firing missions and protected species observation results through the use of mission report forms.
- Air-to-surface gunnery missions will coordinate with next-day flight activities when feasible to provide supplemental post-mission observations for marine mammals in the operations area of the previous day.
- A summary annual report of marine mammal observations and air-to-surface gunnery activities will be submitted to the NMFS Southeast Regional Office (SERO) and the Office of Protected Resources either at the time of a request for renewal of the IHA/LOA, or 90 days after the expiration of the current permit if a new permit is not requested. This annual report must include the following information:
  - Date and time of each air-to-surface gunnery exercise;
  - A complete description of the pre-exercise and post-exercise activities related to mitigating and monitoring the effects of gunnery exercises on marine mammal populations;
  - Results of the monitoring program, including numbers by species/stock of any marine mammals noted injured or killed as a result of the gunnery exercises, and number of marine mammals (by species if possible) that may have been harassed due to presence within the activity zone; and
  - A detailed assessment of the effectiveness of sensor-based monitoring in detecting marine mammals in the area of gunnery operations.

- If any dead or injured marine mammals are observed or detected prior to mission activities, or injured or killed during live fire activities, a report must be made to NMFS by the following business day.
- Any unauthorized takes of marine mammals (i.e., injury or mortality) must be immediately reported to NMFS and to the respective stranding network representative.

14. RESEARCH

Although Eglin AFB does not currently conduct independent monitoring efforts, Eglin's Natural Resources Section does participates in marine animal tagging and monitoring programs lead by other agencies. Additionally, the Natural Resources has also supported participation in annual surveys of marine mammals in the Gulf of Mexico with NMFS. From 1999 to 2002, Eglin Natural Resources, through a contract representative, participated in summer cetacean monitoring and research opportunities. The contractor participated in visual surveys in 1999 for cetaceans in the Gulf of Mexico, photographic identification of sperm whales in the northeastern Gulf in 2001, and as a visual observer during the 2000 Sperm Whale Pilot Study and the 2002 sperm whale Satellite-tag (S-tag) cruise. In addition, Eglin's Natural Resources Section has obtained Department of Defense funding for two marine mammal habitat modeling projects. The latest such project (2008) included funding for and extensive involvement of NMFS personnel so that the most recent aerial survey data could be utilized for habitat modeling and animal density estimates in the northeastern Gulf of Mexico.

Eglin conducts other research efforts which utilize marine mammal stranding information as a potential means of ascertaining the effectiveness of mitigation techniques. Stranding data is collected and maintained for the Florida panhandle area as well as Gulf-wide. This task is undertaken through the establishment and maintenance of contacts with local, state, and regional stranding networks. Eglin AFB assists with stranding data collection by maintaining its own team of stranding personnel. In addition to simply collecting stranding data, various analyses are performed. Stranding events are tracked by year, season, and NMFS statistical zone, both Gulf-wide and on the coastline in proximity to Eglin AFB. Stranding data is combined with records of EGTTR mission activity in each water range and analyzed for any possible correlation. In addition to being used as a possible measure of the effectiveness of mission mitigations, stranding data can yield insight into the species composition of cetaceans in the region.

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APPENDIX A

ACOUSTIC MODELING METHODOLOGY

BACKGROUND

Explosives criteria, unlike sonar environmental thresholds, account for an important distinction: broadband effects. Impulsive sources tend to contribute significant energy from tens of Hz, to tens of kHz.

Detonation of an explosive generates a shockwave, followed by bubble pulses. These pulses are less significant than the first shock wave, but their oscillation generates subsequent pressure waves, and hence necessitates consideration of energy accumulation for thresholds rather than mere sound pressure level.

Acoustic modeling of broadband sources can rely on conventional propagation modeling methods, in addition to basic explosive shockwave/bubble-pulse models. Navy/NMFS explosives criteria can be split into three distinct classes:

- Energy Accumulation,
- Peak Pressure, and
- Positive Impulse.

All three classes will be discussed in the following sections.

Most energy thresholds are based on one-third octaves (OTO), except for Level A, which requires total energy accumulation.

SOURCES AND MODELING METHODS

Urick [2] surveys the literature on explosive modeling methodologies quite thoroughly. Many models are derived by both theoretical consideration and empirical observation. The important modeling inputs for general explosives are:

- Net Explosive Weight (NEW), and
- Source depth.

Table A-1. Source Table

	NEW (lbs)	Source Depth (in)
105 mm	4.7	2.5
105 mm Test Round	0.35	2.5
40 mm	0.869	2.5
25 mm	0.0662	2.5

At longer receiving ranges, the shockwave and largest bubble pulse dominates, and an exponential approximation for acoustic pressure is assumed. From the explosive NEW, the following important parameters are estimated:

- Peak pressure p_{max} at one meter, and
- A time constant t_0 ,

both independent of any propagation model. Based on the exponential derivation [2],

$$p(t) = p_{max}\, e^{-t/t_0},$$
$$p_{max} = 21600\,(w^{1/3} / 3.28\,)^{1.13}\ \text{psi},$$
$$t_0 = [(0.058)\,(w^{1/3})\,(3.28 / w^{1/3})^{0.22}\,] / 1000\ \text{msec}$$

one can derive the energy spectral density, (i.e., energy level per Hz) using Fourier analysis [2] (pp. 93), and integrate over a one-third octave band to estimate the effective One-third Octave Energy Source Level (ESL).

$$\text{ESL} = 10\log_{10}(0.26\, f) + 10\log_{10}(\,2\, p_{max}^{\,2} / [1/\theta^2 + 4\,\pi\, f^{\,2}]\,) + 197\ \text{dB}$$

For a single detonation, this ESL can be combined with any transmission loss model—appropriate for the frequency band of interest— to determine received energy level $E_0(f)$ at any range/depth combination, for any one-third octave band based on its center frequency.

PROPAGATION MODEL

Propagation modeling for the EGTTR Environment was modeled using the following databases/models:

- GDEM v3.0
- CASS/GRAB v4.2a
- LFBL v11.1, HFBL v2.2

For maximum flexibility in shallow water environments, two bathymetry environments are modeled: 80 meters, and 160 meters in two seasonal (warm/cold) generic GOMEX environments near EGTTR. [3]

To accommodate the broadband nature of these explosives, TL data are sampled at seven frequencies from 10 Hz to 40 kHz, spaced every two octaves. Eigenrays are propagated and summed in an incoherent fashion to avoid significant range-dependent variation.

SURFACE-IMAGE INTERFERENCE

An important propagation consideration at low frequencies is the effect of surface-image interference. As either source or target approach the surface, pairs of paths that differ by a single surface reflection set up an interference pattern that ultimately causes the two paths to cancel each other when the source or target is at the surface. A fully coherent summation of the eigenrays produces such a result but also introduces extreme fluctuations that would have to be highly sampled in range and depth, and then smoothed to give meaningful results. An alternative approach is to implement what is sometimes called a semi-coherent summation. A semi-coherent sum attempts to capture significant effects of surface-image interference (namely the reduction of the field due to destructive interference of reflected paths as the source or target approach the surface) without having to deal with the more rapid fluctuations associated with a fully coherent sum. The semi-coherent sum is formed by a random phase addition of paths that have already been multiplied by the expression:

$$\sin^2\left(\frac{4\pi f z_s z_a}{c^2 t}\right)$$

where f is the frequency, z_s is the source depth, z_a is the animal depth, c is the sound speed and t is the travel time from source to animal along the propagation path. For small arguments of the sine function this expression varies directly as the frequency and the two depths. It is this relationship that causes the propagation field to go to zero as the depths approach the surface or the frequency approaches zero.

This surface-image interference must be applied across the entire bandwidth of the explosive source. The TL field is sampled at several representative frequencies. However, the image-interference correction given above varies substantially over that frequency spacing. To avoid possible under sampling, the image-interference correction is averaged over each frequency interval.

ENERGY ACCUMULATION

Much like sonar energy thresholds, the 3D energy field is discretized and modeled by reducing the ESL in a one-third octave band by the transmission loss, and finding all grid boxes exceeding the energy threshold, resulting in impact volumes as a function of depth.

Ranges are estimated by assuming cylindrical symmetry around the detonation, finding the depth with greatest volume, and computing this maximum range.

Level A Total-energy accumulation sums energy in all frequency bands before determining the maximum range exceeding the threshold.

PEAK PRESSURE

The peak pressure metric is a simple, straightforward calculation at each range/animal depth combination. First, the transmission ratio, modified by the source level in a one-octave band and the vertical beam pattern, is averaged across frequency on an eigenray-by-eigenray basis. This averaged transmission ratio (normalized by the total broadband source level) is then compared across all eigenrays with the maximum designated as the peak arrival. Peak pressure at that range/animal depth combination is then simply the product of:

- the square root of the averaged transmission ratio of the peak arrival,

- the peak pressure at a range of one meter, and
- the similitude correction (given by $r^{-0.13}$, where r is the slant range along the eigenray estimated as tc with t the travel time along the dominant eigenray and c the nominal speed of sound).

If the peak pressure for a given grid point is greater than the specified threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer. Similarly to energy threshold estimation, a cylindrical assumption around the detonation point determines maximum range over the water column.

MODIFIED POSITIVE-IMPULSE

The modeling of positive impulse follows the work of Goertner [1]. The Goertner model defines a "partial" impulse as

$$\int_0^{T_{\min}} p(t)dt$$

where $p(t)$ is the pressure wave from the explosive as a function of time t, defined so that $p(t) = 0$ for $t < 0$. The upper limit of the "partial" impulse integral is

$$T_{min} = \min \{T_{cut}, T_{osc}\}$$

where T_{cut} is the time to cutoff and T_{osc} is a function of the animal lung oscillation period. When the upper limit is T_{cut}, the integral is the definition of positive impulse. When the upper limit is defined by T_{osc}, the integral is smaller than the positive impulse and thus is just a "partial" impulse. Switching the integral limit from T_{cut} to T_{osc} accounts for the diminished impact of the positive impulse upon the animals lungs that compress with increasing depth and leads to what is sometimes call a "modified" positive impulse metric.

The time to cutoff is modeled as the difference in travel time between the direct path and the surface-reflected path in an isospeed environment. At a range of r, the time to cutoff for a source depth z_s and an animal depth z_a is

$$T_{cut} = 1/c \ \{ [r^2 + (z_a + z_s)^2]^{1/2} - [r^2 + (z_a - z_s)^2]^{1/2} \}$$

where c is the speed of sound.

The animal lung oscillation period is a function of animal mass M and depth z_a and is modeled as

$$T_{osc} = 1.17\, M^{1/3}\, (1 + z_a/33)^{-5/6}$$

where M is the animal mass (in kg) and z_a is the animal depth (in feet).

The modified positive impulse threshold is unique among the various injury and harassment metrics in that it is a function of depth and the animal weight. So instead of the user specifying the threshold, it is computed as $K\ (M/42)^{1/3}\ (1 + z_a/33)^{1/2}$. The coefficient K depends upon the level of exposure. For the onset of slight lung injury, K is 19.7; for the onset of extensive lung hemorrhaging (1% mortality), K is 47.

Although the thresholds are a function of depth and animal weight, sometimes they are summarized as their value at the sea surface for a typical dolphin calf (with an average mass of 12.2 kg). For the onset of slight lung injury, the threshold at the surface is approximately 13 psi-msec; for the onset of extensive lung hemorrhaging (1% mortality), the threshold at the surface is approximately 31 psi-msec.

As with peak pressure, the "modified" positive impulse at each grid point is compared to the derived threshold. If the impulse is greater than that threshold, then the incremental volume for the grid point is added to the impact volume for that depth layer.

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