REQUEST FOR A LETTER OF AUTHORIZATION FOR THE INCIDENTAL HARASSMENT OF MARINE MAMMALS RESULTING FROM THE NAVAL SURFACE WARFARE CENTER PANAMA CITY DIVISION (NSWC PCD) MISSION ACTIVITIES

NAVAL SURFACE WARFARE CENTER PANAMA CITY DIVISION, FLORIDA

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

MARCH 2008

PRINTED ON RECYCLED PAPER

TABLE OF CONTENTS

TABLE OF CONTENTS CONT'D

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

LIST OF ACRONYMS, ABBREVIATIONS, AND SYMBOLS

°C	Degrees Celsius
°F	Degrees Fahrenheit
°N	Degrees North
°S	Degrees South
µPa	Micropascal
3-D	Three-Dimensional
ABR	Auditory Brainstem Response
AFB	Air Force Base
ASW	Anti-Submarine Warfare
CASS-GRAB	Comprehensive Acoustic Simulation System/Gaussian Ray Bundle
CETAP	Cetacean and Turtle Assessment Program
CFR	Code of Federal Regulations
cm	Centimeters
COMPTUEX	Composite Training Unit Exercises
CPA	Closest Points of Approach
dB	Decibels
DBDBV	Digital Bathymetry Data Base Variable Resolution
dB re 1 µPa	Decibels Referenced to 1 Micropascal
dB re 1 µPa^2-s	Decibels Referenced to 1 Micropascal Squared Second
DOC	Department of Commerce
DON	Department of the Navy
EA	Environmental Assessment
EEZ	Exclusive Economic Zone
EFD	Energy Flux Density
EFDL	Energy (Flux Density) Level
EIS	Environmental Impact Statement
EIS/OEIS	Environmental Impact Statement/Overseas Environmental Impact Statement
EL	Energy Flux Density Level
EMF	Electromagnetic Field
ESA	Endangered Species Act
ETP	Eastern Tropical Pacific
FDA	Food and Drug Administration
FEIS	Final Environmental Impact Statement
FM	Frequency Modulated
ft	Feet
ft/sec	Feet per Second
ft/s	Feet per Second
ft^2	Square Feet
ft^3	Cubic Feet
FWC	Florida Fish and Wildlife Conservation Commission
FY	Fiscal Year
GDEM	Generalized Digital Environmental Model
GIS	Geographic Information System
GOM	Gulf of Mexico
GRAB	Gaussian Ray Bundle
HE	High Explosive
HFBL	High-Frequency Bottom Loss
HPA	Hypothalamic-Pituitary-Adrenal

HRC	Hawaii Range Complex
Hz	Hertz
IHA	Incidental Harassment Authorization
in	Inches
in-lb/in^2	Inch Pounds per Square Inch
IWC	International Whaling Commission
J/m^2	Joule per Square Meter
JTFEX	Joint Task Force Exercises
kg	Kilograms
kg/m^3	Kilograms per Cubic Meter
kHz	Kilohertz
km	Kilometers
km/hr	Kilometers per Hour
km^2	Square Kilometers
Kt	Knots
Lb	Pounds
LFA	Low-Frequency Active
LFBL	Low-Frequency Bottom Loss
LIDAR	Light Imaging Detection and Ranging
LLS	Laser Line Scan
L_{max}	Highest Sound Level Measured During a Single Noise Event
LOA	Letter of Authorization
LWAD	Littoral Warfare Advanced Development
m	Meters
m/sec	Meters per Second
m^2	Square Meters
m^3	Cubic Meters
MCM	Mine Countermeasures
MFA	Mid-Frequency Active
MHz	Megahertz
mi^2	Square Miles
MLO	Mine-like Object
mm	Millimeters
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MRA	Marine Resources Assessment
MSAT	Marine Species Awareness Training
msec	Millisecond
NATO	North Atlantic Treaty Organization
NEPA	National Environmental Policy Act
NEW	Net Explosive Weight
NIPTS	Noise-induced Permanent Threshold Shift
NM	Nautical Miles
nm	Nanometer
NM^2	Square Nautical Miles
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	Nuclear Regulatory Commission
NRC	National Research Council
NSA PC	Naval Support Activity Panama City

NSWC PCD	Naval Surface Warfare Center Panama City Division
OEA	Overseas Environmental Assessment
ONR	Office of Naval Research
OPAREAs	Operating Areas
p	Pressure
PBR	Potential Biological Removal
PC	Panama City
PCD	Panama City Division
PL	Public Law
$\mathbf{p_{rms}}$	RMS Pressure
psi	Pounds per Square Inch
psi-msec	Pounds per Square Inch per Millisecond
PTS	Permanent Threshold Shift
RDT&E	Research, Development, Test, and Evaluation
RIMPAC	Rim of the Pacific
rms	Root Mean Square
SAB	St. Andrew Bay
sec	Seconds
SEL	Sound Exposure Level
SI	Source Intensity
SL	Source Level
SNS	Sympathetic Nervous System
SPL	Sound Pressure Level
SURTASS	Surveillance Towed Array Sensor System
SVP	Sound Velocity Profile
TM	Tympanic-Membrane
TNT	Trinitrotoluene
TS	Threshold Shift
TTS	Temporary Threshold Shift
UME	Unusual Mortality Events
U.S.	United States
USC	United States Code
USEPA	U.S. Environmental Protection Agency
USS	United States Ship
USWEX	Undersea Warfare Exercise
UUV	Underwater Unmanned Vehicle
VEM	Versatile Exercise Mine
W	Watts

1. DESCRIPTION OF ACTIVITIES

1.1 INTRODUCTION

The Department of the Navy (DON) has prepared this request for a Letter of Authorization (LOA) in accordance with provisions of Section 101 (a)(5)(A) and (D) of the Marine Mammal Protection Act (MMPA) to cover the taking of marine mammals incidental to Research, Development, Test, and Evaluation (RDT&E) operations that occur within the Naval Surface Warfare Center Panama City Division (NSWC PCD) Study Area. The NSWC PCD Study Area consists of St. Andrew Bay (SAB) and the water underlying military warning areas (areas within the Gulf of Mexico [GOM] subject to military operations) W-151 (includes Panama City Operating Area), W-155 (includes Pensacola Operating Area), and W-470 (Figure 2-1 and Figure 2-2). During these operations, ships, aircraft, and underwater systems would support eight primary RDT&E activities: air operations, surface operations, subsurface operations, sonar operations, electromagnetic operations, laser operations, ordnance operations, and projectile firing.

The Marine Mammal Protection Act (MMPA) of 1972, as amended (16 United States Code (USC) Section (§) 1371(a)(5)), authorizes the issuance of regulations and LOAs for the incidental taking of marine mammals by a specified activity for a period of not more than five years. The issuance occurs when the Secretary of Commerce, after notice has been published in the Federal Register and opportunity for comment has been provided, finds that such takes will have a negligible impact on the species and stocks of marine mammals and will not have an unmitigable adverse impact on their availability for subsistence uses. The National Marine Fisheries Service (NMFS) has promulgated implementing regulations under 50 Code of Federal Regulations (CFR) § 216.101–106 that provide a mechanism for allowing the incidental, but not intentional, taking of marine mammals while engaged in a specified activity.

This document has been prepared in accordance with the applicable regulations and the MMPA, as amended by the National Defense Authorization Act for Fiscal Year (FY) 2004 (Public Law [PL] 108-136). The basis of this request is the analysis of spatial and temporal distributions of marine mammals in the NSWC PCD Study Area, a review of RDT&E activities that have the potential to affect marine mammals, and a technical risk assessment to determine the likelihood of effects to marine mammals from the RDT&E activities.

This chapter describes RDT&E activities conducted by the United States (U.S.) Navy that could expose marine mammals to sound likely to result in Level B harassment (i.e., temporary threshold shift [TTS] and behavioral effects) and possibly Level A harassment (i.e., permanent threshold shift [PTS]), under the MMPA of 1972. The Navy is requesting that NMFS authorize the incidental taking of marine mammals pursuant to the MMPA, with the issuance of a final rule by May 01, 2009.

1.2 PURPOSE AND NEED

The ***Purpose*** of the Proposed Action is to enhance NSWC PCD's capability and capacity to meet littoral and expeditionary warfare requirements by providing RDT&E and in service engineering for expeditionary maneuver warfare, operations in extreme environments, mine warfare, maritime operations, and coastal operations.

The ***Need*** for the Proposed Action is for the Navy to successfully meet current and future national and global defense challenges by developing a robust capability to research, develop, test, and evaluate systems within the NSWC PCD Study Area. This capability allows the Navy to meet its statutory mission to deploy worldwide naval forces equipped to meet existing and emergent threats and to enhance its ability to operate jointly with other components of the armed forces. NSWC PCD was established on the current site maintained by NSA PC after a thorough site selection process in 1942. The Navy considered locations along the East Coast and in the GOM. NSWC PCD provides:

- Accessibility to deep water
- Tests in clear water
- Conducive sand bottom
- Available land and sheltered areas, and
- Average good weather (year –round testing).

In addition to these requirements for testing, the area was selected based on the moderate cost of living, the availability of personnel, and the low level of crowding from industries and development. In 1945, the station was re-commissioned as the U.S. Navy mine countermeasure station after its turnover as a Section Base for amphibious forces in 1944. The factors identified in 1942 during the selection process solidified the decision.

NSWC PCD provides the greatest number of favorable circumstances for the environment needed to conduct RDT&E focused on mine countermeasures, economically and efficiently. Many of the other locations have large amounts of ship traffic, rough waters and windy conditions, and closure of water ways seasonally due to water level. NSWC PCD has the established infrastructure, equipment, and personnel as well as the conditions required to fulfill the Proposed Action.

1.3 DESCRIPTION OF NSWC PCD RDT&E AND IN-SERVICE SUPPORT ACTIVITIES

NSWC PCD is the U.S. Navy's premier research and development organization focused on littoral (coastal region) warfare and expeditionary (designed for military operations abroad) warfare. NSWC PCD provides RDT&E and in-service support for expeditionary maneuver warfare, operations in extreme environments, mine warfare, maritime (ocean-related) operations, and coastal operations. The mission descriptions associated with these mission areas are as follows:

- ***Expeditionary Maneuver Warfare* –** Includes the rapid clearing of surf and beach zone mines and obstacles, rapid and reliable marking of breached lanes (paths that are safe for vessel travel within a minefield), and reliable precision navigation inside these marked lanes.
- ***Operations in Extreme Environments* –** Involves activities ranging from deep salvage to routine hull maintenance; all aspects of diving and life support requirements are addressed.
- ***Mine Warfare* –** Includes research, modeling, development, engineering, and testing of mine and mine countermeasures (MCM) systems; threat mine exploitation (evaluation of non-U.S. mines); mine and MCM tactics development; systems or platform integration (ensuring that all aspects, communications, logistics, and software, of the systems and equipment used during a test operation do not conflict with each other); and mine and MCM life-cycle management.
- ***Maritime Operations* –** Provides focused technical expertise supporting research, development, and acquisition of special operations maritime systems and equipment. The primary types of support include: Manned Undersea Mobility Systems; Diving and Life Support Systems; Underwater Guidance and Navigation Systems; Outboard Engine Systems; and Unmanned Systems.
- ***Coastal Operations* –** Involves applying the knowledge and technology developed for military and warfighting arenas to diverse existing and emerging civil, commercial, and academic needs, such as coastal and maritime security.

1.3.1 Description of Proposed Action

The Proposed Action is to improve NSWC PCD's capabilities to conduct new and increased mission operations for the DON and other customers. The DON is evaluating potential environmental effects associated with the littoral and expeditionary warfare activities proposed for the NSWC PCD Study Area, which includes military warning areas W-151 (includes Panama City Operating Area), W-155 (includes Pensacola Operating Area), W-470, and SAB. NSWC PCD's activities occur either on or over the waters present within the NSWC PCD Study Area. All shoreside support activities are managed by Naval Support Activity Panama City (NSA PC). No hazardous waste is generated at sea during NSWC PCD RDT&E activities. This LOA request will evaluate only the in-water activities related to NSWC PCD's RDT&E activities conducted within the NSWC PCD Study Area, and will not address routine shoreside management functions performed by NSA PC.

1.3.2 NSWC PCD RDT&E Activities

NSWC PCD provides RDT&E and in-service support for expeditionary maneuver warfare, operations in extreme environments, mine warfare, maritime (ocean-related) operations, and coastal operations. A variety of naval assets, including ships, aircraft, and underwater systems support the aforementioned mission activities for eight primary test operations that occur within or over the water environment up to the high water mark. These operations include air, surface, and subsurface operations, sonar, electromagnetic energy, laser, ordnance, and projectile firing. A brief overview of the eight RDT&E activities is provided in the following paragraphs.

Air Operations

Aircraft platforms are often an essential part of the RDT&E activities conducted by NSWC PCD. The majority of the aircraft utilized to support the RDT&E activities are helicopters (MH-53, MH-60, UH-1, and variants). When multiple aircraft are required to support a test, one aircraft is usually designated as the test platform and the other aircraft are used for surveying and monitoring to determine that a particular test site is clear of other aircraft or surface vessels. Four subcategories make up the types of RDT&E activities conducted from aircraft platforms within the NSWC PCD Study Area. They include (1) support activities (for clearance and monitoring), (2) tows (of an object that contains active or passive sensors towed in the water column), (3) captive carriage (to test the handling of aircraft during transport, separation, and release of shapes [objects that represent towed systems]), and (4) aerial separation of expendables (to test inert shapes, rockets, and/or mines and the aircraft's flight effects on deployment). The fourth area includes the only form of live aerial expendables, which includes gun firing at predetermined targets from a helicopter. This operation does not contribute to the incidental taking of marine mammal species as stated in the NSWC PCD EIS/OEIS.

Surface Operations

A significant portion of NSWC PCD RDT&E relies on surface operations to successfully complete missions. Four subcategories make up the surface operations category. They include support activities, tows, deployment and recovery of equipment and systems development. Section 1.3.3.1 provides additional information on the activities encompassed by surface operations.

Subsurface Operations

Subsurface operations include diving, salvage, robotic vehicles, UUVs, and mooring and burying of mines. The Diving and Life Support Division conducts fundamental research in support of underwater life-support equipment and systems, which include specific dive operations ranging from deep salvage to routine hull maintenance. NSWC PCD also supports the naval special warfare arena by testing manned undersea mobility systems, underwater guidance, and navigation systems.

NSWC PCD diving personnel, comprised of both military and civilian divers, are responsible for providing diving and salvage services (i.e., planting and recovering mine-like objects [MLOs]/inert mines and Versatile Exercise Mines [VEMs]) associated with locating and recovering RDT&E equipment jettisoned and/or placed into the NSWC PCD Study Area. In addition to human divers, the use of UUVs and robotic vehicles such as crawlers that locate, classify and/or map underwater mines also makes up a portion of the subsurface activities at NSWC PCD. Crawlers are fully autonomous, battery-powered amphibious vehicles that are used for functions such as reconnaissance missions in territorial waters. The body of a representative crawler measures 72 centimeters (cm) (28 inches [in]) in length, 62 cm (24 in) in width and are 28 cm (11 in) high. On average, these devices weigh an estimated 41 kilograms [kg] (90 pounds [lb]) and are used to classify and map underwater mines in the surf zone. Typically UUVs are battery-powered; however, some of the larger UUVs are diesel-powered. UUVs are typically propeller-driven and are capable of sustaining speeds of several knots. The body shape and size of UUVs varies in accordance with its launch platform, recovery platform, and overall mission. Historically, the UUVs tested at NSWC PCD have included vehicles of various sizes ranging from 32 cm (1 foot [ft]) to 7 meters (m) (23 ft) in length with a diameter of 25 cm (10 in) to 122 cm (4 ft) in width.

Finally, the NSWC PCD also develops, upgrades, and manages new underwater mine systems, which makes up the final subcategory of subsurface operations. In order to meet the specifications and operational requirements associated with developing such systems, testing is required to collect the data and information used to analyze the functionality of the system during various stages of development. In addition, other mine warfare testing conducted at NSWC PCD requires the placement of temporary minefields at varying depths (surf zone to 183 m [600 ft]) within the NSWC PCD Study Area. Temporary minefields placed in support of NSWC PCD testing typically consist of moored MLO/inert mines (i.e., any inert object or casing that resembles the shape of a mine/mines without the explosive component), and/or VEMs (i.e., mine casings containing programmable electronics and sensors used to simulate a mine and collect data). These test fields remain in the water throughout the test cycle. Live mines could be used in future tests that involve mine countermeasures to test the efficiency and survivability of the system.

Sonar Operations

NSWC PCD sonar operations involve the testing of various sonar systems in the ocean and laboratory environment as a means of demonstrating the system's software capability to detect, locate, and characterize MLOs under various environmental conditions. The data collected is used to validate the sonar systems' effectiveness and capability to meet its mission. Section 1.3.3.2 contains specific information on sonar operations.

Electromagnetic Operations

NSWC PCD develops and tests an array of magnetic sensors that generate electromagnetic fields (EMF) used in MCM operations. NSWC PCD demonstrates the capability and effectiveness of deploying such sensors from aircrafts and surface ship platforms in the territorial and non-territorial waters of the NSWC PCD Study Area. In doing so, multiple sweeps are conducted over specified test areas containing both tethered MLOs and totally buried MLOs/inert mines and VEMs in an effort to demonstrate the systems' effectiveness to influence or trigger magnetic targets. NSWC PCD has experimented with deploying magnetic sensors onboard unmanned underwater swimming and crawling vehicles and has conducted tests to evaluate individual sensor capabilities during high-speed operations. This operation does not contribute to the incidental taking of marine mammal species as stated in the NSWC PCD EIS/OEIS.

Laser Operations

Laser test operations conducted within the NSWC PCD Study Area take place both below and above the water surface. Systems employed by the Navy include light imaging detection and ranging (LIDAR), laser line scan (LLS), and directional systems. Generally, the LIDAR systems are mounted on a helicopter and emit a narrow, high frequency laser beam. When the laser light beam hits the water, part of the energy is reflected off the surface and the rest travels through the water column and reflects off targets in the water column or off the sea floor itself. The directional systems are mounted on moving platforms and are identical to the LIDAR systems but are utilized under water. The LIDAR systems that would be tested within the NSWC PCD Study Area are very similar to those LIDAR systems used by the National Oceanic and Atmospheric Administration (NOAA) to map benthic habitats. The LLS has been developed for use on towed bodies and UUVs. Unlike the LIDAR systems, the LLS systems are employed under water. In its simplest form, the LLS system is a sensor that takes advantage of a laser to concentrate intense light over a small area in order to illuminate distant targets. The LLS system is a commercial off-the-shelf system utilized by agencies such as NOAA to map underwater habitat and bottom contours. NSWC PCD is testing the capability of this technology in identifying MLOs. This operation does not contribute to the incidental taking of marine mammal species as stated in the NSWC PCD EIS/OEIS.

Ordnance Operations

Ordnance operations are encompassed by this LOA application. NSWC PCD has become the leader in developing naval airborne, surface, organic (readily available units in place), and shallow water MCM systems. Real life test scenarios using live explosives are required to demonstrate the capability and effectiveness of the MCM systems currently being developed and tested at NSWC PCD. Ordnance operations involve the detonation of mines that weigh up to 272 kg (600 lb) and the testing of line charges that consist of a 107 m (350 ft) detonation cord with explosives lined from one end to the other end in 2 kg (5 lb) increments and total 794 kg (1,750 lb) of net explosive weight (NEW). Section 1.3.3.3 provides additional information on ordnance operations in the NSWC PCD Study Area.

Projectile Firing Operations

Finally, the capability to use gunfire during test operations was identified as a future requirement. Rounds (individual shots) identified include 5-in, 20-millimeter (mm), 25-mm, 30-mm, 40-mm, 76-mm, and various small arms ammunition (i.e., standard target ammunition). Section 1.3.3.4 gives more information on projectile firing conducted in the NSWC PCD Study Area.

1.3.3 Basis for Operations Addressed in this LOA Request

The remainder of this document addresses only mission components analyzed in the NSWC PCD Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) that may result in the incidental taking of marine mammal species. Operational activities that have been identified in the past, which have the potential to affect the underwater environment in regions outside of the NSWC PCD Study Area, include surface, sonar, ordnance, and projectile firing operations. Air operations, electromagnetic operations and laser operations are eliminated from further discussion in this LOA because these actions would not take marine mammal species as discussed in the NSWC PCD EIS/OEIS. Experience and historical data collected during previous NSWC PCD operations has never revealed any negative reports of effects associated with any of the activities encompassed within the NSWC PCD Study Area. Furthermore, the public has never made any significant complaints related to these testing operations. Therefore, this request includes only the operational activities that have potential to affect the underwater environment in NSWC PCD Study Area. The following subsections provide details on these operations including the number of test events proposed for each category.

1.3.3.1 Surface Operations

NSWC PCD RDT&E activities involving surface operations may result in incidental harassment of marine mammals. The Proposed Action includes up to 7,443 hours of surface operations per hour in the NSWC PCD Study Area. As stated previously, four subcategories make up surface operations. The following paragraphs provide details for each of these activities.

The first subcategory is support activities, which are required by nearly all of the testing missions within the NSWC PCD Study Area. The size of these vessels varies in accordance with the test requirements and vessel availability. Often multiple surface crafts are required to support a single test event. Acting as a support platform for testing, these vessels are utilized to carry test equipment and personnel to and from the test sites and are also used to secure and monitor the designated test area. Normally, these vessels remain on site and return to port following the completion of the test; occasionally, however, they remain on-station throughout the duration of the test cycle for guarding sensitive equipment in the water. Testing associated with these operational capabilities may include a single test event or a series of test events spread out over consecutive days or as one long test operation that requires multiple days to complete.

The remaining subcategories of additional support include tows, deployment and recovery of equipment, and systems development. Tows are also conducted from ships at the NSWC PCD to test system functionality. Tow tests of this nature involve either transporting the system to the designated test area where it is deployed and towed over a pre-positioned inert minefield or towing the system from NSWC PCD to the designated test area. Surface vessels are also utilized as a tow platform for systems that are designed to be deployed by helicopters. Surface craft are also used to perform the deployment and recovery of underwater unmanned vehicles (UUVs), sonobuoys, inert mines, MLOs, VEM systems, and other test systems. Surface vessels that are used in this manner normally return to port the same day. However, this is test dependent, and under certain circumstance (e.g., endurance testing), the vessel may be required to remain on site for an extended period of time. Finally, RDT&E activities also encompass testing of new, alternative, or upgraded hydrodynamics, and propulsion, navigational, and communication software and hardware systems.

1.3.3.2 Sonar Operations

NSWC PCD sonar operations involve the testing of various sonar systems in the ocean and laboratory environment as a means of demonstrating the systems' software capability to detect, locate, and characterize mine-like objects under various environmental conditions. The data collected is used to validate the sonar system's effectiveness and capability to meet its mission.

As sound travels through water, it creates a series of pressure disturbances. Frequency is the number of complete cycles a sound or pressure wave occurs per unit of time (measured in cycles per second, or hertz [Hz]). The Navy has characterized low, mid, or high frequency as follows:

- **Low frequency –** Below 1 kilohertz (kHz) (low frequency will not be used during any NSWC PCD operations)
- **Mid-frequency –** From 1 to 10 kHz (proposed NSWC PCD operations would use a small number of mid-frequency sound sources)
- **High frequency –** Above 10 kHz (the majority of NSWC PCD operations would use high frequency sound sources)

Low frequency sonar is not proposed to be used during NSWC PCD operations. The various sonar systems proposed to be tested within the NSWC PCD Study Area range in frequencies of 1 kHz to 5 megahertz (MHz) (5,000 kHz). The source levels associated with NSWC PCD sonar systems that require analysis in this document based on the systems' parameters range from between 200 decibels (dB) at 1 m to 250 dB at 1 m. The sonar systems tested are typically part of a towed array or hull mounted to a vessel. Additionally, subsystems associated with a UUV or surf zone crawler operation are included. Operating parameters of the sonar systems used at NSWC PCD can be found in Appendix A, Supplemental Information for Underwater Noise Analysis.

Table 1-1 provides an overall summary of the total tempos associated with the preferred alternative. The table includes number hours of operation for mid-frequency and high frequency sonar testing activities for territorial and non-territorial waters, respectively. The ranges for the operations are given in the column, where appropriate. For example, sonar operations are divided into mid-frequency and high-frequency ranges. The three columns to the left of the double vertical line contain the amount of operations for each subcategory conducted in territorial waters of the NSWC PCD Study Area. The values to the right of this demarcation, except those contained in the last column of the table, indicate the number of hours and/or operations that would occur in the non-territorial waters. The final column provides the total number of hours and/or operations in the NSWC PCD Study Area (or tempo in the territorial waters plus tempo in the non-territorial waters).

1.3.3.3 Ordnance Operations

Ordnance operations include live testing of ordnance of various net explosive weights and line charges. The following subsections provide an overview of the events for ordnance and line charges, respectively.

Ordnance

Live testing is only conducted after a system has successfully completed inert testing and an adequate amount of data has been collected to support the decision for live testing. Testing with live targets or ordnance is closely monitored and uses the minimum number of live munitions necessary to meet the testing requirement. Depending on the test scenario, live testing may occur from the surf zone out to the outer perimeter of the NSWC PCD Study Area. The Navy requires the capability to conduct ordnance operations in shallow water to clear surf zone areas for sea-based expeditionary operations. The size and weight of the explosives used varies from 0.91 to 272 kg (2 to 600 lb) trinitrotoluene (TNT) equivalent NEW depending on the test requirements. For this document, ordnance was analyzed based on three ranges of NEW: 0.45 to 4.5 kg (1 to 10 lb), 5 to 34 kg (11 to 75 lb), and 34.5 to 272 kg (76 to 600 lb). Detonation of ordnance with a NEW less than 34.5 kg (76 lb) are conducted in territorial waters and detonations of ordnance with a NEW greater than 34.5 kg (76 lb) are conducted in non-territorial waters.

Line Charges

Line charges consist of a 107 m (350 ft) detonation cord with explosives lined from one end to the other end in 2 kg (5 lb) increments and total 794 kg (1,750 lb) of NEW. The charge is considered one explosive source that has multiple increments that detonate at one time. The Navy proposes to conduct up to three line charge events in the surf zone. Line charge testing will only be conducted in the surf zone along the portion of Santa Rosa Island that is part of Eglin Air Force Base (AFB). The Navy must develop a capability to safely clear surf zone areas for sea-based expeditionary operations. To that end, NSWC PCD occasionally performs testing on various surf zone clearing systems that use line charges to neutralize mine threats. These tests are typically conducted from a surface vessel (e.g., Landing Craft Air Cushion [LCAC]) and are deployed using either a single or dual rocket launch scenario. This is a systems development test and only assesses the in-water components of testing.

Table 1-1 also provides an overview of ordnance testing at NSWC PCD. Section 1.3.3.2 provides an explanation for the format of the table.

1.3.3.4 Projectile Firing

Current projectile firing includes 50 rounds of 30- millimeter (mm) ammunition each year within the NSWC PCD Study Area. The No Action Alternative detailed in Section 2.3.1 would encompass these rounds. The capability of utilizing gunfire during test operations was identified as a future requirement. Rounds (individual shots) identified include 5 inch, 20 millimeter (mm), 25 mm, 30 mm, 40 mm, 76 mm, and various small arms ammunition (i.e., standard target ammo). Projectiles associated with these rounds are mainly armor-piercing projectiles. The 5-in round is a high explosive (HE) projectile containing approximately 3.63 kg (8 lbs) of explosive material. Current projectile firing includes 50 rounds of 30-mm ammunition each year within the NSWC PCD Study Area. The preferred alternative would provide for increases in the number of 30-mm rounds as well as for expansion of projectile firing operations to 5 in, 20 mm, 40 mm, 76 mm, 25 mm, and small arms ammunition. All projectile firing will occur over non-territorial waters.

Table 1-1. Description of NSWC PCD Proposed Action

SONAR OPS (hrs/yr)	*Territorial Waters* Medium (1 kHz-10 kHz)	*Territorial Waters* High (>10 kHz)	*Non-Territorial Waters* Medium (1 kHz-10 kHz)	*Non-Territorial Waters* High (>10 kHz)	*Total* Hrs/yr
	73	822	4	455	1,354*

ORDNANCE OPS (dets/yr) (lines/yr)	Territorial Detonations: Range 1 (0–10 lb) (0.45 to 4.5 kg) (dets/yr)	Territorial Detonations: Range 2 (11–75 lb) (4 to 34 kg) (dets/yr)	Territorial Detonations: Range 3 (76–600 lb) (34 to 272 kg) (dets/yr)	Non-Territorial Detonations: Range 1 (0–10 lb) (0.45 to 4.5 kg) (dets/yr)	Non-Territorial Detonations: Range 2 (11–75 lb) (4 to 34 kg) (dets/yr)	Non-Territorial Detonations: Range 3 (76–600 lb) (34 to 272 kg) (dets/yr)	Items/yr
Detonations	51	3	0	0	0	16	70
Line charges**	3			0			3

Projectile Firing (rnds/yr)	Territorial: 5 in	40mm	30mm	20mm	76mm	25mm	Small Arms	Non-Territorial: 5 in	40mm	30mm	20mm	76mm	25mm	Small Arms	Items/yr
	0	0	0	0	0	0	0	60	480	600	2,967	240	525	6,000	10,872

dets = detonations; hrs = hours; lb = pounds; rnds = rounds; ops = operations; yr = year; kHz = kilohertz; kg = kilogram

*An additional 150 hours (144 territorial hrs/6 non-territorial hours) for jamming and mechanical minesweeping devices occurring over broad frequency ranges are not included in this estimate. These systems were not included in the analysis because no power source is used to generate the acoustic output and the mechanical device generates the acoustic output similar to Navy ships. Movement of ships through the water is not associated with acoustic impact on marine mammals; mechanical devices would not affect marine mammals.

**Line charges = 794 kg (1,750 lb) net explosive weight, which is evenly distributed along a 107-m (350-ft) detonation cord

2. DATES, DURATION, AND LOCATION OF THE TEST ACTIVITIES

This Naval Surface Warfare Center Panama City Division (NSWC PCD) Letter of Authorization (LOA) request addresses all of the Research, Development, Test, and Evaluation (RDT&E) operations involving sonar, ordnance and line charges, and projectile firing that occur in the NSWC PCD Study Area, which includes St. Andrew Bay (SAB) and military warning areas (areas within the Gulf of Mexico [GOM] subject to military operations) W-151 (includes Panama City Operating Area), W-155 (includes Pensacola Operating Area), and W-470 (Figure 2-1 and Figure 2-2). The NSWC PCD Study Area includes a Coastal Test Area, a Very Shallow Water Test Area, and Target and Operational Test Fields. The NSWC PCD RDT&E activities may be conducted anywhere within the existing military operating areas and SAB from the mean high water line (average high tide mark) out to 222 kilometers (km) (120 nautical miles [NM]) offshore (Figures 2-1 and 2-2). The locations and environments include:

- Test area control sites adjacent to NSWC PCD.
- Wide coastal shelf 97 km (52 NM) distance offshore to 183 meters (m) [600 feet (ft)], including bays and harbors.
- Water temperature range of 27 degrees Celsius (°C) [80 degrees Fahrenheit (°F)] in summer to 10 °C (50 °F) in winter.
- Typically sand bottom and good underwater visibility.
- Seas less than 0.91 m (3 ft) 80 percent of the time (summer) and less than 0.91 m (3 ft) 50 percent of the time (winter).

NSWC PCD mission activities are ongoing and this LOA request is for a time period of five years beginning July 2009. All operations are conducted randomly throughout the year. RDT&E operations vary in frequency and duration.

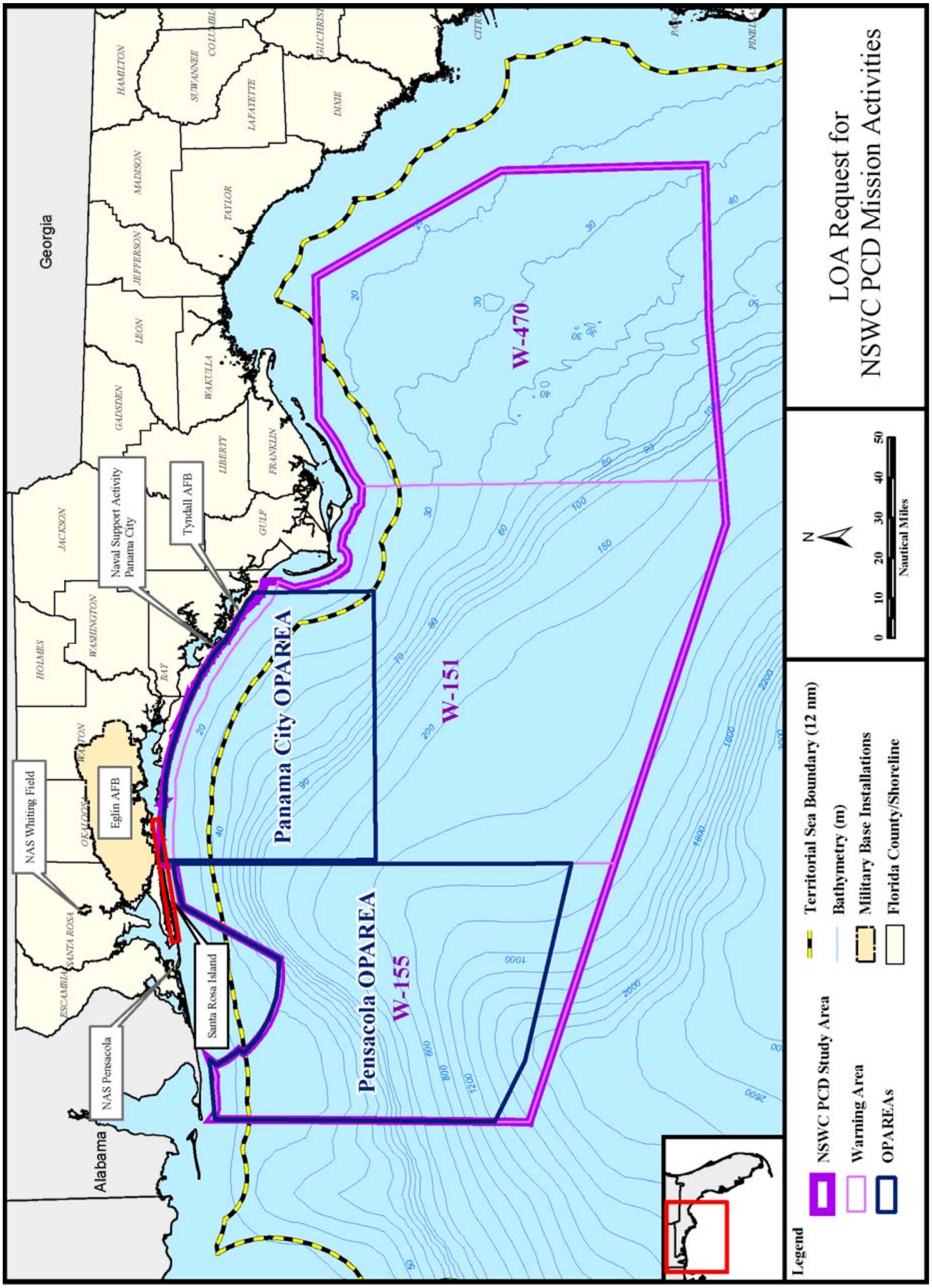


Figure 2-1. NSWC PCD Study Area: GOM

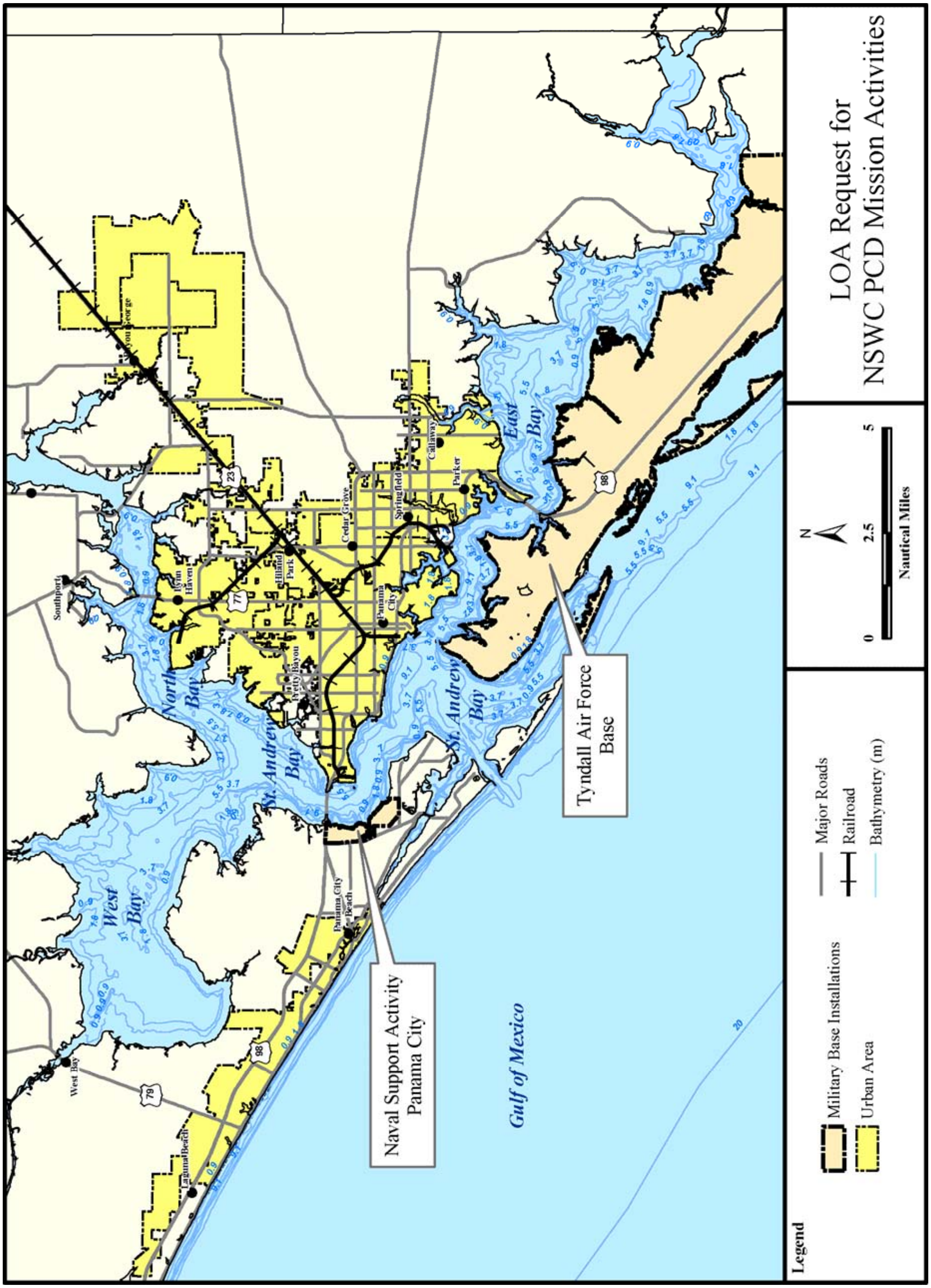


Figure 2-2. The NSWC PCD Study Area: Nearshore Environments and SAB

This page is intentionally blank.

3. MARINE MAMMAL SPECIES AND OCCURRENCE

The Marine Mammal Protection Act (MMPA), which is administered by the National Marine Fisheries Service (NMFS) and the U.S. Fish and Wildlife Service (USFWS), protects all marine mammals in United States (U.S.) waters. Twenty-nine marine mammal species may occur in the Naval Surface Warfare Center Panama City Division (NSWC PCD) Study Area (28 cetaceans [whales and dolphins] and one sirenian species [manatees]). Twenty-one of these marine mammal species regularly occur here. Of those marine mammals potentially occurring in St. Andrew Bay and the NSWC PCD Study Area, the following seven marine mammals are currently listed as endangered under the Endangered Species Act:

- North Atlantic right whale
- Humpback whale
- Sei whale
- Fin whale
- Blue whale
- Sperm whale
- West Indian manatee

A separate consultation is underway pursuant to Section 7 of the Endangered Species Act (ESA) with NMFS to evaluate potential effects to these species as relevant to the act.

Marine Mammal Occurrence

Marine mammals are generally defined as mammals that depend upon the sea for all or most of their life needs. Cetaceans may be further categorized as mysticetes or odontocetes. Mysticetes use baleen plates to filter small prey items from the water column, whereas odontocetes use teeth to capture prey.

Cetaceans inhabit most marine environments, from deep ocean canyons to shallow estuarine waters. However, they are not randomly distributed. Marine mammal distribution is affected by demographic, evolutionary, ecological, habitat-related, and anthropogenic factors (Bjørge, 2002; Forcada, 2002; Stevick et al., 2002). Species occurring off the continental shelf are often associated with physical features that tend to concentrate prey, such as banks, canyons, or the shelf edge. Cetacean movements are often related to breeding or feeding (Stevick, 2002). Cetacean occurrence and movement has also been linked to indirect prey indicators such as temperature variations, sea surface chlorophyll *a* concentrations, and features such as bottom depth (Fiedler, 2002). Occurrence may also be related to oceanographic features such as upwelling events or warm-core rings. The increased nutrient concentrations associated with upwelling results in areas of high primary productivity. These areas of high primary production cause a cascading effect on the trophic dynamics of marine animals; upwelling areas are generally associated with higher-than-average levels of consumers such as copepods, fish, and cetaceans. Marine mammals have also been associated with warm-core rings that have pinched off the Gulf Stream current. Many species, including sperm whales (*Physeter macrocephalus*), were associated with the periphery of Gulf Stream warm-core rings, probably due to the increased productivity and presence of prey species around the rings (Warring et al, 2001; Griffin, 1999).

Some baleen whale species, such as humpback and North Atlantic right whales, make extensive annual migrations to low-latitude mating and calving grounds in the winter and to high-latitude feeding grounds in the summer (Corkeron and Connor, 1999). These migrations undoubtedly occur during these seasons due to the presence of highly productive waters and associated cetacean prey species at high latitudes and warm water temperatures at low latitudes (Corkeron and Connor, 1999; Stern, 2002). Not all baleen whales, however, migrate. Some individual fin (*B. physalus*) and blue (*B. musculus*) whales may stay year-round in a specific area. The timing of migration is often a function of age, sex, and reproductive class. Females tend to migrate earlier than males and adults earlier than immature animals (Stevick et al., 2002). Since most toothed whales do not have the fasting capability of the baleen whales, toothed whales probably either follow seasonal shifts in preferred prey or are opportunistic feeders, taking advantage of whatever prey happens to be in the area.

A variety of marine mammals occur in the Gulf of Mexico (GOM). Most of the cetaceans occurring in the GOM are odontocetes. Very few baleen whales exist in the GOM and all species except the Bryde's whale would not be expected to occur within the NSWC PCD Study Area given the preference of these species for deeper waters. Fourteen species of oceanic dolphins, four species of beaked whales, and ten species of whales belonging to four families inhabit or migrate through the eastern GOM. Of the ten whale species, six species are listed under the ESA as endangered. Five of these six whales have been only rarely sighted in the eastern GOM. They include the blue whale, the fin whale, the humpback whale, the northern right whale, and the sei whale. The lone sirenian, the West Indian manatee, is also infrequently recorded in the eastern GOM.

Cetaceans considered to be common in the GOM include the Atlantic bottlenose dolphin (*Tursiops truncatus*), the pantropical spotted dolphin (*Stenella attenuata*), the Atlantic spotted dolphin (*Stenella plagiodon*), and the striped dolphin (*Stenella coeruleoalba*). Of all whale species in the GOM, the endangered sperm whales (*Physeter macrocepalus*) are the most abundant (Waring et al., 2007). Table 3-1 presents the cetaceans sighted within the NSWC PCD Study Area as determined in a Navy technical report (Department of the Navy [DON], 2003a).

Table 3-2 provides an overview of the best and minimum population estimates for marine mammal stocks by region in the NSWC PCD Study Area, which are calculated by NMFS officials in their Stock Assessment Reports. This table addresses only the species that are expected to be in the NSWC PCD Study Area and that were analyzed in this document. Stocks and regions are provided because some species, in this case the Atlantic bottlenose dolphin, have been divided by NMFS officials into different stocks based on their anatomical, genetic, and/or behavioral characteristics.

Table 3-1. Marine Mammals with Sighting Records in the GOM

Common Name	Scientific Name	Status	Location
Suborder Mysticeti (baleen whales)			
Family Balaenopteridae (rorquals)			
North Atlantic right whale	*Eubalaena glacialis*	Endangered	GOM
Humpback whale	*Megaptera novaeangliae*	Endangered	
Sei whale	*Balaenoptera borealis*	Endangered	GOM
Fin whale	*Balaenoptera physalus*	Endangered	GOM
Blue whale	*Balaenoptera musculus*	Endangered	GOM
Bryde's whale	*Balaenoptera edeni*		GOM
Minke whale	*Balaenoptera acutorostrata*		GOM
Suborder Odontoceti (toothed whales)			
Family Physeteridae (sperm whale)			
Sperm whale	*Physeter macrocephalus*	Endangered	GOM
Family Kogiidae			
Pygmy sperm whale	*Kogia breviceps*		GOM
Dwarf sperm whale	*Kogia sima*		GOM
Family Ziphiidae (beaked whales)			
Cuvier's beaked whale	*Ziphius cavirostris*		GOM
Gervais' beaked whale	*Mesoplodon europaeus*		GOM
Blainville's beaked whale	*Mesoplodon densirostris*		GOM
Sowerby's beaked whale	*Mesopolodon bidens*		GOM
Family Delphinidae (dolphins)			
Rough-toothed dolphin	*Steno bredanensis*		GOM
Bottlenose dolphin	*Tursiops truncatus*		GOM
Pantropical spotted dolphin	*Stenella attenuata*		GOM
Atlantic spotted dolphin	*Stenella frontalis*		GOM
Spinner dolphin	*Stenella longirostris*		GOM
Clymene dolphin	*Stenella clymene*		GOM
Striped dolphin	*Stenella coeruleoalba*		GOM
Fraser's dolphin	*Lagenodelphis hosei*		GOM
Risso's dolphin	*Grampus griseus*		GOM
Melon-headed whale	*Peponocephala electra*		GOM
Pygmy killer whale	*Feresa attenuata*		GOM
False killer whale	*Pseudorca crassidens*		GOM
Killer whale	*Orcinus orca*		GOM
Long-finned and short-finned pilot whale	*Globicephala macrorhynchus*		GOM
Order Sirenia			
Family Trichechidae (manatees)			
West Indian manatee	*Trichechus manatus*	Endangered	GOM

Source: DON, 2007

Table 3-2. Best and Minimum Population Estimates for Marine Mammals in the GOM Calculated by NMFS

Species	Stock	Best Population Estimate	Minimum Population Estimate
Bryde's Whale	Northern GOM	40	25
Sperm Whale	Northern GOM	1,349	1,114
Dwarf and Pygmy Sperm Whale	Northern GOM	742	584
Mesoplodon sp. (Blainville's & Gervais Beaked Whales)	Northern GOM	106	76
Cuvier's Beaked Whale	Northern GOM	95	65
Sowerby's Beaked Whale	Western North Atlantic	NA	NA
Killer Whale	Northern GOM	133	90
False Killer Whale	Northern GOM	1,038	606
Pygmy Killer Whale	Northern GOM	408	256
Risso's Dolphin	Northern GOM	2,169	1,668
Rough-toothed Dolphin	Northern GOM	2,223	1,595
Atlantic Bottlenose Dolphin	Coastal, Eastern GOM	9,912	8,963
Atlantic Bottlenose Dolphin	GOM Bay Sound and Estuarine (SAB)	124	79
Atlantic Bottlenose Dolphin	Continental Shelf &Slope	25,320	20,414
Atlantic Bottlenose Dolphin	GOM Oceanic	2,239	1,607
Atlantic Bottlenose Dolphin	Northern GOM Coastal	4,191	3,518
Atlantic Spotted Dolphin	Northern GOM	30,947	24,752
Pantropical Spotted Dolphin	Northern GOM	91,321	79,879
Striped Dolphin	Northern GOM	6,505	4,599
Spinner Dolphin	Northern GOM	11,971	6,990
Clymene Dolphin	Northern GOM	17,355	10,528
Florida Manatee	Northern GOM	Unknown	1,822
Fraser's Dolphin	Northern GOM	726	427

NA Not applicable; OCS = Outer Continental Shelf
Source: Waring et al., 2007; USFWS, 2000

This page is intentionally blank.

4. AFFECTED SPECIES STATUS AND DISTRIBUTION

Cetaceans have a number of anatomical and physiological adaptations to the aquatic environment. Compared to terrestrial mammals, body heat conservation is more efficient due to the presence of blubber and the circulatory adjustments made to minimize heat loss. Many marine mammals are also capable of prolonged and deep dives. Characteristics that enable such dives include flexible ribs that allow the lungs to collapse, thickened tissue in the middle ear, slowed heart rate, reduced oxygen consumption, and shunting of blood to essential tissues during dives. Sensory abilities also vary somewhat from those of terrestrial mammals. Hearing is extremely important to cetaceans because sound travels further in water than in air. In addition, light attenuation in water decreases the distance of the visual range of marine mammals and therefore, marine mammals use hearing in place of vision. Vocalization is used to navigate, forage, and socialize. Produced sound often extends above and below the range of human hearing. Baleen whales primarily use low frequencies (0.20 to 3 kilohertz [kHz]). Odontocetes typically use high frequencies, but produce a wide range of frequencies. Direct experimental data on cetacean hearing ability are sparse, particularly for the larger species. It is generally believed that these animals should at least be sensitive to the frequencies of their own vocalizations. Scientists have determined auditory thresholds for a few dolphin species in captivity. Studies of the anatomy of cetacean inner ears and models of the structural properties provide an indication of possible sensitivity to various sound frequencies. The ears of small, toothed whales appear to be optimized to hear high frequencies, while baleen whale ears are likely most sensitive to low frequencies.

This chapter provides detailed information on the population characteristics for the affected species in the Naval Surface Warfare Center Panama City Division (NSWC PCD) Study Area. Descriptions include the distribution of animals in the Gulf and abundance estimates. As defined in Chapter 2, NSWC PCD activities take place in territorial and non-territorial waters of W-151 (includes Pensacola Operating Area [OPAREA]), W-155 (includes Panama City OPAREA), and W-470 in the GOM and in St. Andrew Bay (SAB). Of the approximately 29 species with occurrence records in the NSWC PCD Study Area, 19 species regularly occur here. The other 10 species are extralimital and are excluded from further consideration of impacts from NSWC PCD testing missions. The following sections describe marine mammal occurrence in the NSWC PCD Study Area.

The Navy Marine Resources Assessment (MRA) program was implemented by the Commander, United States (U.S.) Fleet Forces Command, to collect data and information on the protected and commercial marine resources found in the Department of the Navy's (DON's) operating areas. Specifically, the goal of the MRA program is to describe and document the marine resources present in each of the Navy's Operating Areas. As such, an MRA has been completed for the GOM Testing and Training Areas, which comprise three adjacent Operating Areas, one of which is the Panama City Operating Area (DON, 2007).

The MRA represents a compilation and synthesis of available scientific literature (e.g., journals, periodicals, theses, dissertations, project reports, and other technical reports published by government agencies, private businesses, or consulting firms) and NMFS (2003) reports, including stock assessment reports, recovery plans, and survey reports. The MRAs summarize the physical environment (e.g., marine geology, circulation and currents, hydrography, and plankton and primary productivity) for each test area. In addition, an in-depth discussion of the biological environment (marine mammals, sea turtles, fish, and EFH), as well as fishing grounds (recreational and commercial) and other areas of interest (e.g., maritime boundaries, navigable waters, marine managed areas, recreational diving sites) are also provided. Where applicable, the information contained in the Marine Resources Assessment (MRA) was used for this Letter of Authorization (LOA).

The MRA uses a particular convention to describe marine mammal occurrence throughout the Navy's OPAREAs. The specific terms used and their corresponding meanings are as follows:

- **Expected occurrence** is defined as the area encompassing the expected distribution of a species based on what is known of its habitat preferences, life history, and the available stranding, sighting, and fisheries' incidental by-catch data.
- **Extralimital occurrence** is defined as the area where species occasionally occur in very small numbers.
- **Low/unknown occurrence** is an area where the likelihood of encountering a species is rare or there is not sufficient data to support a more definitive conclusion.
- **Occurrence not expected** is the area where a species is not expected to be encountered.

The MRA data were used to provide a regional context for each species. The data were compiled from available sighting records, literature, satellite tracking, and stranding and by-catch data.

4.1 MYSTICETES

The following mysticetes have possible or confirmed occurrence in the GOM.

North Atlantic Right Whale (*Eubalaena glacialis*)

Description – North Atlantic right whales are 9 to 17 m (30 to 56 ft) long with a stout body shape. The head is covered with irregular, whitish patches called "callosities" that assist researchers in individual identification. North Atlantic right whales feed on zooplankton, particularly large calanoid copepods such as *Calanus*. Feeding behavior has been observed in all of the northern high-use areas such as Cape Cod Bay, the Bay of Fundy, the Great South Channel, and Roseway Basin in the western North Atlantic but has not been observed on the calving grounds or during migration. Until recently, right whales in the North Atlantic and North Pacific were classified together as a single species referred to as the "northern right whale." Genetic data indicate that these two populations represent separate species: the North Atlantic right whale (*Eubalaena glacialis*) and the North Pacific right whale (*Eubalaena japonica*).

Status – The North Atlantic right whale is the world's most endangered large whale species, and is classified as endangered under the ESA. This species is presently declining in number and is considered to be reproductively dysfunctional. The western stock of the North Atlantic right whale is a strategic stock because the average annual fishery-related mortality and serious injury exceeds PBR.

A review of the photo-identification recapture database in October 2005 indicated that 306 individually recognized whales were known to be alive during 2001 (Waring et al., 2007). Therefore, the latest minimum population estimate for the western North Atlantic stock of right whales is estimated at 306 individuals.

Distribution – North Atlantic right whales occur in subpolar to temperate waters, primarily in continental shelf waters between Florida and Nova Scotia. Right whales might be seen anywhere off the Atlantic U.S. throughout the year and typically follow a well-defined seasonal migratory pattern. This species is most often found in very shallow, nearshore waters and in cooler sea surface temperatures inshore of a mid-shelf front winter calving grounds. High whale densities can extend more northerly than the current defined boundary of the calving critical habitat in response to interannual variability in regional sea surface temperatures distribution.

Eighty-four percent of right whales found in the mid-Atlantic are sighted between December and April, with peaks in December, March, and April. Further, Knowlton et al. (2002) reviewed mid-Atlantic right whale sightings and survey efforts and reported that 94.1 percent of the right whale sightings were within 55 kilometer (km) (30 NM) of the coast, 63.8 percent were within 18.5 km (10 NM) of the coast, and 80 percent of all tagged animal sightings occurred within 55 km (30 NM) of land. Knowlton et al. (2002) also noted the majority of sightings greater than 55 km (30 NM) from the coast occur off New York and southern New England (i.e., at the northern extent of the range of the study). While there may be concern that the Knowlton study has a data bias in that a larger effort was put forth in the nearshore region, such concern does not seem to be warranted, as an extensive offshore study effort was conducted, and both the satellite tag data and the effort data show these animals seem to prefer nearshore waters (Knowlton et al., 2002). In addition, Hain and Kenney (2005) concurred with Knowlton that a majority of right whale sightings occur within 55 km (30 NM) of the shore.

Most northern right whale sightings follow a well-defined seasonal migratory pattern through several consistently utilized habitats. It should be noted, however, that some individuals may be sighted in these habitats outside the typical time of year and that migration routes are poorly known (there may be a regular offshore component). The population migrates as two separate components, although some whales may remain in the feeding grounds throughout the winter. Pregnant females and some juveniles migrate from the feeding grounds to the calving grounds off the southeastern United States in late fall to winter. The cow-calf pairs return northward in late winter to early spring. The majority of the right whale population leaves the feeding grounds for unknown habitats in the winter but returns to the feeding grounds coinciding with the return of the cow-calf pairs. Some individuals as well as cow-calf pairs can be seen through the fall and winter on the feeding grounds with feeding observed.

During the spring through early summer, northern right whales are found on feeding grounds off the northeastern United States and Canada. Individuals may be found in Cape Cod Bay in

February through April and in the Great South Channel east of Cape Cod in April through June. Right whales are found throughout the remainder of summer and into fall (June through November) on two feeding grounds in Canadian waters. The peak abundance is in August, September, and early October. The majority of summer/fall sightings of mother/calf pairs occur east of Grand Manan Island (Bay of Fundy), although some pairs might move to other unknown locations. Jeffreys Ledge appears to be important habitat for right whales, with extended whale residences; this area appears to be an important fall feeding area for right whales and an important nursery area during summer. The second feeding area is off the southern tip of Nova Scotia in the Roseway Basin between Browns, Baccaro, and Roseway Banks. The Cape Cod Bay and Great South Channel feeding grounds are formally designated as critical habitats under the ESA.

During the winter (as early as November and through March), northern right whales may be found in coastal waters off North Carolina, Georgia, and northern Florida. The waters off Georgia and northern Florida are the only known calving ground for western northern right whales; it is formally designated as a critical habitat under the ESA. Calving occurs from December through March. On January 1, 2005, the first observed birth on the calving grounds was reported. The majority of the population is not accounted for on the calving grounds, and not all reproductively active females return to this area each year.

Radio-tagged animals have made extensive movements, sometimes traveling from the Gulf of Maine into deeper waters off the continental shelf. Mate et al. (1997) tagged one male that traveled into waters with a bottom depth of 4,200 m (13,780 ft). Long-distance movements as far north as Newfoundland, the Labrador Basin, southeast of Greenland, Iceland, and Arctic Norway have been documented. One individually identified right whale was documented to make a two-way trans-Atlantic migration from the East Coast to a location in northern Norway. A female northern right whale was tagged with a satellite transmitter and tracked to nearly the middle of the Atlantic where she remained for a period of months.

The coastal waters of the Carolinas are suggested to be a migratory corridor for the right whale. The Southeast U.S. Coast Ground, consisting of coastal waters between North Carolina and northern Florida, was mainly a winter and early spring (January-March) right whaling ground during the late 1800s. The whaling ground was centered along the coasts of South Carolina and Georgia. An examination of sighting records from all sources between 1950 and 1992 found that wintering right whales were observed widely along the coast from Cape Hatteras, North Carolina, to Miami, Florida. Sightings off the Carolinas were comprised of single individuals that appeared to be transients. These observations are consistent with the hypothesis that the coastal waters of the Carolinas are part of a migratory corridor for the right whale. Knowlton et al. (2002) analyzed sightings data collected in the mid-Atlantic from northern Georgia to southern New England and found that the majority of right whale sightings occurred within approximately 56 km (30 NM) from shore. Until better information is available on the right whale's migratory corridor, it has been recommended that management considerations are needed for the coastal areas along the mid-Atlantic migratory corridor within 65 km (35 NM) from shore.

The following three areas occur in U.S. waters and were designated by NMFS as critical habitat in June 1994 (NMFS, 2005b):

- Coastal Florida and Georgia (Sebastian Inlet, Florida, to the Altamaha River, Georgia),
- The Great South Channel, east of Cape Cod, and
- Cape Cod and Massachusetts Bays.

The northern critical habitat areas serve as feeding and nursery grounds, while the southern area from the mid-Georgia coast extending southward along the Florida serves as calving grounds. The waters off Georgia and northern Florida are the only known calving ground for western North Atlantic right whales. The physical features correlated with the distribution of right whales in the southern critical habitat area provide an optimum environment for calving. For example, the bathymetry of the inner and nearshore-middle shelf area minimizes the effect of strong winds and offshore waves, limiting the formation of large waves and rough water. The average temperature of critical habitat waters is cooler during the time right whales are present due to a lack of influence by the Gulf Stream and cool freshwater runoff from coastal areas. NMFS theorizes the water temperatures provide an optimal balance between offshore waters that are too warm for nursing mothers to tolerate, yet not too cool for calves that may only have minimal fatty insulation.

During January and February, there is a possible southward shift in whale distribution toward warmer sea surface temperatures in the region monitored by the early warning system (i.e., Right Whale Sighting Advisory System). However, in the relatively warmer and southernmost survey zone (nearshore waters of Florida), right whales concentrate in the northern, cooler portion. Warm Gulf Stream waters appear to represent a thermal limit (both southward and eastward) for right whales.

Diving Behavior **–** Dives of 5 to 15 min or longer have been reported, but can be much shorter when feeding. Foraging dives in the known feeding high-use areas are frequently very near the bottom of the water column. The average depth of a right whale dive is strongly correlated with both the average depth of peak copepod abundance and the average depth of the bottom mixed layer's upper surface. Right whale feeding dives are characterized by a rapid descent from the surface to a particular depth between 80 and 175 m (262 to 574 ft), remarkable fidelity to that depth for 5 to 14 min and then rapid ascent back to the surface. Longer surface intervals have been observed for reproductively active females and their calves. The longest tracking of a right whale is of an adult female, which migrated 1,928 km (1,198 miles) in 23 days (mean=3.5 kilometers/hour (km/hr), or 2.2 miles/hr) from 40 km (25 miles) west of Browns Bank (Bay of Fundy) to Georgia.

Acoustics and Hearing **–** North Atlantic right whales produce a variety of sounds, including moans, screams, gunshots, blows, upcalls, downcalls, and warbles, that are often linked to specific behaviors. North Atlantic right whale sound production rates (duration of calls and interval between calls) are also highly variable. Most of these sounds range in frequency from 0.02 to 15 kHz (dominant frequency range from 0.02 to <2 kHz; durations typically range from 0.01 to multiple seconds) with some sounds having multiple harmonics. Source levels for some of these sounds have been measured as ranging from 137 to 192 dB re 1 μPa-m root mean square (rms). In certain regions (i.e., northeast Atlantic), preliminary results indicate that right whales vocalize more from dusk to dawn than during the daytime.

Vocalization rates of North Atlantic right whales are also highly variable, and individuals have been known to remain silent for hours. Right whales commonly produce calls in a series of 10 to 15 calls lasting 5 to 10 minutes, followed by silence lasting an hour or more; some individuals do not call for periods of at least four hours. Frequencies of these vocalizations are between 50 and 500 hertz (Hz); typical sounds are in the 300 to 600 Hz range with up- and down-sweeping modulations, with lower (<200 Hz) and higher (>900 Hz) frequency sounds being relatively rare. Source levels have been estimated only for pulsive calls of North Atlantic right whales, which are 172 to 187 decibels with a reference pressure of one micropascal at one meter (dB re 1 μPa-m).

Morphometric analyses of North Atlantic right whale inner ears estimates a hearing range of approximately 0.01 to 22 kHz, based on established marine mammal models. Exposure to short tones and down sweeps, ranging in frequency from 0.5 to 4.5 kHz, induced an alteration in behavior (received levels of 133 to 148 dB re 1 μPa-m), but exposure to sounds produced by vessels (dominant frequency range of 0.05 to 0.5 kHz) did not produce any behavioral response (received levels of 132 to 142 dB re 1 μPa-m).

Occurrence in NSWC PCD Study Area – There is a low or unknown occurrence of right whales in the GOM. However, there are five confirmed records for the GOM; all of them occurred in winter and spring, including one stranding on the Texas coast in 1972. Three of the sightings were of cow-calf pairs. One pair seen in late January 2004 off Miami, Florida and in mid-March to early April off the Florida Panhandle was later resighted in June in waters off Cape Cod. More recently, a cow-calf pair was photographed in Corpus Christi Bay off southern Texas and sighted a few weeks later off Long Boat Key, Florida. These records are probably of extralimital strays from the wintering grounds off the southeastern U.S. The highly endangered status of the North Atlantic right whale, however, necessitates an extremely conservative determination of this species' occurrence in this area. There is a low or unknown occurrence of right whales east of the vicinity of the Mississippi River Delta from the 10 m (33 ft) isobath into deeper waters. The predicted occurrence reflects the known distribution of sightings off the U.S. Atlantic coast. Sightings have been recorded throughout the year off the southeastern U.S., so it is possible that any of those individuals could accidentally make their way into the GOM during any part of the year. In stock assessment reports, National Oceanic and Atmospheric Administration (NOAA) Fisheries does not include right whales among those species having populations or stocks in the northern GOM.

Humpback Whale (*Megaptera novaeangliae*)

Description – Humpback whale adults are 11 to 16 m (36 to 53 ft) in length and are more robust or less streamlined than other rorquals (any large streamlined baleen whale with a small pointed dorsal fin and grooves running longitudinally on the throat). Humpbacks use a wide variety of behaviors to feed on various small, schooling prey including krill and fish. The principal fish prey species in the western North Atlantic are sand lance (*Ammodytes americanus*), herring (family *Clupidae*), and capelin (*Millotus villoses*).

Status – Humpback whales are classified as endangered under the ESA, and therefore, considered to be a strategic stock under the MMPA. An estimated 11,570 humpback whales occur in the entire North Atlantic, which includes an estimated 902 humpback whales (minimum of 647 animals) that comprise the Gulf of Maine stock (Waring et al., 2007). A considerable amount of information has been gathered on humpback biology, especially on their feeding and calving grounds, since 1970 (Lowry et al., 2007).

Distribution – Humpback whales are found in all of the world's oceans, generally on their high-latitude feeding grounds, which are located from south of New England to northern Norway, from spring through fall and in the tropics where calving occurs during the winter, with migration occurring between the two areas. In the North Atlantic Ocean, humpbacks are found from the Caribbean Sea and Cape Verde Islands to Greenland, Iceland, and northern Norway. Most humpback whale sightings are in nearshore and continental shelf waters; however, humpback whales frequently travel through deep water during migration. During the winter, most of the North Atlantic population of humpback whales is believed to migrate south to calving grounds in the West Indies region. Routes taken during southbound and northbound migrations are not known. Recently there has been an increasing occurrence of humpbacks, which appear to be primarily juveniles, during the winter along the U.S. Atlantic coast from Florida north to Virginia.

In the North Atlantic Ocean, humpbacks are found from spring through fall on feeding grounds that are located from south of New England to northern Norway. The Gulf of Maine is one of the principal summer feeding grounds for humpback whales in the North Atlantic. The largest numbers of humpback whales are present from mid-April to mid-November. Feeding locations off the northeastern United States include Stellwagen Bank, Jeffreys Ledge, the Great South Channel, the edges and shoals of Georges Bank, Cashes Ledge, Grand Manan Banks, the banks on the Scotian Shelf, the Gulf of St. Lawrence, and the Newfoundland Grand Banks. Distribution in this region has been largely correlated to prey species and abundance, although behavior and bottom topography are factors in foraging strategy. Humpbacks typically return to the same feeding areas each year.

The distribution and abundance of sand lance are important factors underlying the distribution patterns of the humpback whale. Changes in diets and feeding preferences are likely caused by changes in prey distribution and/or in the relative abundance of different prey species (sand lance and herring). Feeding most often occurs in relatively shallow waters over the inner continental shelf and sometimes in deeper waters. Large multi-species feeding aggregations (including humpback whales) have been observed over the shelf break on the southern edge of Georges Bank and in shelf break waters off the U.S. mid-Atlantic coast.

During the winter, most of the North Atlantic population of humpback whales are believed to migrate south to calving grounds in the West Indies region. Due to the temporal difference in occupancy of the West Indies between individuals from different feeding areas, coupled with sexual differences in migratory patterns, Stevick et al. (2003b) suggested the possibility that there are reduced mating opportunities between individuals from different high-latitude feeding areas. The calving peak is January through March, with some animals arriving as early as December and a few not leaving until June. The mean sighting date in the West Indies for individuals from the United States and Canada is February 16 and 15, respectively.

Apparently, not all Atlantic humpback whales migrate to the calving grounds, since some sightings (believed to be only a very small proportion of the population) are made during the winter in northern habitats. The sex/age class of nonmigratory animals remains unclear. A small number of individuals remain in the Gulf of Maine during winter; however, it is not known whether these few sightings represent winter residents or either late-departing or early-arriving migrants.

Diving Behavior – Humpback whale diving behavior depends on the time of year. In summer, most dives last less than 5 minutes (min); those exceeding 10 min are atypical. In winter (December through March), dives average 10 to 15 min; dives of greater than 30 min have been recorded. Although humpback whales have been recorded to dive as deep as about 500 m, on the feeding grounds they spend the majority of their time in the upper 120 m of the water column. Recent research revealed that humpbacks are usually only a few meters below the water's surface while foraging. Humpback whales on the wintering grounds can dive deeply; dives have been recorded deeper than 100 m.

Acoustics and Hearing – Humpback whales are known to produce three classes of vocalizations: (1) "songs" in the late fall, winter, and spring by solitary males; (2) sounds made within groups on the wintering (calving) grounds; and (3) social sounds made on the feeding grounds.

The best-known types of sounds produced by humpback whales are songs, which are thought to be breeding displays used only by adult males. Singing is most common on breeding grounds during the winter and spring months, but is occasionally heard outside breeding areas and out of season. Humpback song is an incredibly elaborate series of patterned vocalizations which are hierarchical in nature. There is geographical variation in humpback whale song, with different populations singing different songs, and all members of a population using the same basic song. However, the song evolves over the course of a breeding season, but remains nearly unchanged from the end of one season to the start of the next.

Social calls are from 50 Hz to over 10 kHz, with the highest energy below 3 kHz. Female vocalizations appear to be simple, while the male song is complex and changes between seasons. Components of the song range from under 20 Hz to 4 kHz and occasionally 8 kHz, with source levels of 144 to 174 dB re 1 µPa m, with a mean of 155 dB re 1 µPa-m. High-frequency harmonics of humpback songs have been recorded out to 13.5 kHz, and source levels between 171 and 189 dB re 1 µPa-m. Songs have also been recorded on feeding grounds. The main energy lies between 0.2 and 3.0 kHz, with frequency peaks at 4.7 kHz.

Feeding calls, unlike song and social sounds, are highly stereotyped series of narrow-band trumpeting calls. They are 20 Hz to 2 kHz, less than 1 sec in duration, and have source levels of 162 to 192 dB re 1 µPa-m. The fundamental frequency of feeding calls is approximately 500 Hz.

No tests on humpback whale hearing have been made. A humpback whale audiogram has been constructed using a mathematical model based on the internal structure of the ear. The predicted audiogram indicates sensitivity to frequencies from 700 Hz to 10 kHz, with maximum relative sensitivity between 2 and 6 kHz. Recent information on the songs of humpback whales suggests that their hearing may extend to frequencies of at least 24 kHz and source levels of 151-173 dB re 1µPa (Au et al., 2006).

Occurrence in the NSWC PCD Study Area **–** Humpback whales found in the GOM are likely strays, having made their way into the GOM during the breeding season or on their return migration northward. In the whaling days, humpback whales were occasionally hunted near the Florida Keys. Based on sightings, strandings, and life history parameters, there is a low or unknown occurrence of humpback whales in the NSWC PCD Study Area east of the Mississippi River Delta during fall, winter, and spring from the shore, over the continental shelf, and into waters with a bottom depth greater than 3,000 m (9,842.5 ft). This takes into consideration that humpback whales migrate to calving grounds in the Caribbean during the fall and making return migrations to the feeding grounds much further north during the spring. During the summer, humpback whales should occur further north on their feeding grounds and are, therefore, not expected anywhere in the NSWC PCD Study Area. Humpback whales have been sighted quite close to shore off the western coast of Florida, as well as in waters seaward of the continental shelf break. In February 2004, an individual was sighted off the west coast of Florida. This individual was identified as "Fingerpaint," a humpback whale known to inhabit the Gulf of Maine. Fingerpaint was resighted in September later that year in the Gulf of Maine. These sighting patterns match nearshore and offshore sightings of humpback whales off the U.S. Atlantic coast and in the Caribbean.

Sei Whale (*Balaenoptera borealis*)

Description **–** Adult sei whales can grow to 18 m (59 ft) in length; they are extremely similar in appearance to Bryde's whales and difficult to differentiate at sea or even when stranded on the beach. The taxonomy of the baleen whale group formerly known as sei and Bryde's whales is currently confused and highly controversial. Sei whales feed by "gulping" and "skimming." In the North Atlantic, the major prey species are *Calanus finmarchicus* (copepod), *Meganyctiphanes norvegica* (krill), and *Thysanoessa inermis* (krill).

Status **–** The sei whale is listed as endangered under the ESA and as a depleted and strategic stock under the MMPA. The International Whaling Commission (IWC) recognizes three sei whale stocks in the North Atlantic: Nova Scotia, Iceland-Denmark Strait, and the Northeast Atlantic. The Nova Scotia Stock occurs in U.S. Atlantic waters. A minimum population size for sei whales in the U.S. Atlantic Exclusive Economic Zone (EEZ) is unknown, and there are no recent abundance estimates for the sei whale Nova Scotia Stock (Waring et al., 2006). There has been no directed research program on sei whales in the U.S. since 1970, and information is limited to survey sighting reports, stranding records, and a handful of isolated studies (Lowry et al., 2007).

Distribution **–** Sei whales have a worldwide distribution, but are found primarily in cold temperate to subpolar latitudes, rather than in the tropics or near the poles. They are found in all oceans but are more restricted to mid-latitude temperate waters than other rorquals. In the northwestern Atlantic Ocean, sei whales occur primarily in deep water from Georges Bank north to Davis Strait. The distribution of the Nova Scotia stock might extend along the U.S. coast to at least North Carolina. Sei whales are not common in U.S. Atlantic waters, and are uncommon in most tropical regions. Sei whales are also known for occasional sudden increases in occurrence in areas followed by disappearances for sometimes decades.

Sei whales spend the summer months feeding in the subpolar higher latitudes and return to the lower latitudes to calve in winter. There is some evidence from whaling catch data of differential migration patterns by reproductive class, with females arriving at and departing from feeding areas earlier than males. For the most part, the location of winter breeding areas remains a mystery. Peak abundance in U.S. waters occurs in spring (mid-March through mid-June), primarily around the edges of Georges Bank. Sei whales appear to prefer regions of steep bathymetric relief, such as the continental shelf break or submarine canyons. These areas are often the location of persistent hydrographic features, which may be important factors in concentrating prey.

Like other rorquals, the sei whale undertakes long migrations during spring and fall. The hypothesis is that the Nova Scotia stock moves from spring feeding grounds on or near Georges Bank, to the Scotian Shelf in June and July, eastward to perhaps Newfoundland and the Grand Banks in late summer, then back to the Scotian Shelf in fall, and offshore and south in winter. In the western North Atlantic Ocean, sei whales occur primarily from Georges Bank north to Davis Strait (northeast Canada, between Greenland and Baffin Island). Peak abundance in U.S. waters occurs from winter through spring (mid-March through mid-June), primarily around the edges of Georges Bank. The distribution of the Nova Scotia stock might extend along the U.S. coast at least to North Carolina. As noted by Reeves et al. (1999a), reports in the literature from any time before the mid-1970s are suspect because of the frequent failure to distinguish sei from Bryde's whales, particularly in tropical to warm-temperate waters where Bryde's whales are generally more common than sei whales.

***Diving Behavior* –** There are no reported diving depths or durations for Sei whales.

***Acoustics and Hearing* –** Sei whale vocalizations have been recorded only on a few occasions. They consist of paired sequences (0.5 to 0.8 sec, separated by 0.4 to 1.0 sec) of 7 to 20 short (4 milliseconds [msec]) frequency modulated sweeps between 1.5 and 3.5 kHz; source level is not known. These mid-frequency calls are distinctly different from low-frequency tonal and frequency swept calls recently recorded in the Antarctic; the average duration of the tonal calls was 0.45±0.3 sec, with an average frequency of 433±192 Hz and a maximum source level of 156±3.6 dB re 1 μPa-m. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

***Occurrence in NSWC PCD Study Area* –** There are only five reliable sei whale records for the GOM, three of which are from strandings in eastern Louisiana and one from the Florida Panhandle. Sei whales are uncommon in most tropical regions, and based on the scarcity of records for this species in the GOM, this species is not expected to occur in the GOM. Any sightings would be considered extralimital for this species.

Fin Whale (*Balaenoptera physalus*)

***Description* –** The fin whale is the second-largest whale species, with adults reaching 24 m (79 ft) in length. Fin whales feed on a wide variety of small, schooling prey (especially herring, capelin, and sand lance), including squid and crustaceans (krill and copepods). Fin whales are the dominant large cetacean species in all seasons in the northwestern North Atlantic Ocean with the largest standing stock. Fin and sei whales are very similar in appearance, resulting in some confusion about the distribution of both species.

Status **–** There have been very few studies of fin whales in U.S. waters since 1970, and information on abundance, population dynamics, and trends is very limited (Lowry et al., 2007). The fin whale is listed as endangered under the ESA and, therefore, is considered to be a strategic stock under the MMPA. The best estimate of abundance for western North Atlantic fin whales is 2,814, but this number is underestimated because the data are not corrected for animals missed while diving (Waring et al., 2007). It is more likely that 5,000 to 6,000 fin whales occur off the eastern U.S.

Distribution – Fin whales are broadly distributed throughout the world's oceans, usually in temperate to polar latitudes and less commonly in the tropics. In general, fin whales are more common north of about 30ºN than they are in tropical zones. The overall range of fin whales in the North Atlantic extends from the GOM/Caribbean and Mediterranean north to Greenland, Iceland, and Norway. Fin whales are the dominant large cetacean species in all seasons in the North Atlantic and have the largest standing stock and food requirements. The fin whale is also the most common whale species acoustically detected with Navy deepwater hydrophone arrays in the North Atlantic.

Fin whales are believed to follow the typical baleen whale migratory pattern, with a population shift north into summer feeding grounds and south for the winter. However, the location and extent of the wintering grounds are poorly known. Peak acoustic detections of fin whales occurred in winter throughout the deep water of the North Atlantic, supporting the widely-held hypothesis about their migration. A definite southward movement of the species was detected in the fall with a northward shift in spring; the endpoints of most of the migration routes in the northwestern Atlantic were Newfoundland/Labrador and from south of Bermuda into the West Indies. Migration routes are otherwise unknown. Fin whales are not completely absent from northeast U.S. continental shelf waters in winter, indicating that not all members of the population conduct a full seasonal migration. Additional information on reproductive areas and seasons for this species is not available.

Diving Behavior – Fin whales typically dive for 5 to 15 min, separated by sequences of 4 to 5 blows at 10 to 20 sec intervals. Significant differences can be seen in blow intervals, dive times, and blows per hour between surface feeding and non-surface-feeding fin whales. Fin whales may dive to 97.8 m (321 ft) with a duration of 6.3 min when foraging (feeding) and to 59.2 m (194 ft) with a duration of 4.2 min when not foraging. Fin whale dives have been documented to exceed 150 m (492 ft), coinciding with the diel migration of krill.

Acoustics and Hearing **–** Fin and blue whales produce calls with the lowest frequency and highest source levels of all cetaceans. Infrasonic, pattern sounds have been documented for fin whales. Fin whales produce a variety of sounds with a frequency range up to 750 Hz. The long, patterned 15 to 30 Hz vocal sequence is most typically recorded; only males are known to produce these. The most typical fin whale sound is a 20 Hz infrasonic pulse (actually an Frequency Modulated [FM] sweep from about 23 to 18 Hz) with durations of about 1 sec and can reach source levels of 184 to 186 dB re 1 µPa-m (maximum up to 200). It was recently suggested that these long, patterned vocalizations might function as male breeding displays, much like those that male humpback whales sing. The source depth, or depth of calling fin whales, has been reported to be about 49 m (161 ft). While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Occurrence in NSWC PCD Study Area – Throughout the year, there is a low or unknown occurrence of fin whales east of the Mississippi River Delta from the continental shelf break to the 2,000 m (6,562 ft) isobath. This is based on the distribution of year-round records of either strandings or sightings. During the summer, fin whales should be found on their feeding grounds further north off the northeastern United States; however, there are sighting records in the NSWC PCD Study Area during this time of year. The GOM might represent a part of the range of a low-latitude fin whale population in the northwestern Atlantic or that a small relict population is resident in this area. However, it is more likely that these records might be extralimital and that these fin whale individuals are simply accidental occurrences.

Blue Whale (*Balaenoptera musculus*)

Description – Blue whales are the largest living animals; adults in the Northern Hemisphere reach 22.9 to 28 m (75.1 to 91.9 ft) in length. Blue whales feed primarily on euphausiids (krill).

Status – Blue whales are classified as endangered under the ESA and, therefore, are considered to be a strategic stock. At least two discrete populations are found in the North Atlantic. One ranges from West Greenland to New England and is centered in eastern Canadian waters; the other is centered in Icelandic waters and extends south to northwest Africa. There are no current estimates of abundance for the North Atlantic blue whale population. The 308 recognizable individuals from the Gulf of St. Lawrence area are considered to be a minimum population estimate for the western North Atlantic stock (Waring et al., 2007).

Distribution – Globally, blue whales are primarily found in deep, offshore waters and are rare in shallow, shelf waters. Blue whales are distributed from the ice edge to the subtropics in both hemispheres. Stranding and sighting data suggest that the blue whale's original range in the Atlantic extended south to Florida, the GOM, the Cape Verde Islands, and the Caribbean Sea. Researchers using the Navy's integrated undersea surveillance system have been able to detect blue whales throughout the open North Atlantic Ocean south to at least the Bahamas, suggesting that North Atlantic blue whales may comprise a single stock. Blue whales are often sighted in the waters off eastern Canada, with the majority of recent records from the Gulf of St. Lawrence. The blue whale rarely occurs in the U.S. Atlantic EEZ, which may represent the limits of its feeding range. Sightings in the Gulf of Maine and U.S. EEZ have been made in late summer and early fall (August and October). The winter range of most rorquals (blue, fin, sei, and minke whales) is hypothesized to be in offshore waters. Acoustic data support the hypothesis of an offshore wintering habitat. Information on reproductive areas and seasons for this species is not available.

Diving Behavior – Blue whales spend greater than 94% of their time below the water's surface. Blue whales can dive to an average of 140 m (459 ft) and for 7.8 min when foraging and to 67.6 m (222 ft) and for 4.9 min when not foraging. However, dives deeper than 300 m (984 ft) have been recorded from tagged individuals.

Acoustics and Hearing – Blue and fin whales produce calls with the lowest frequency and highest source levels of all cetaceans. Sounds are divided into two categories: short-duration or long-duration. Blue whale vocalizations are typically long, patterned, low-frequency sounds with durations up to 36 seconds repeated every 1 to 2 min. Their frequency range is 12 to 400 Hz, with dominant energy in the infrasonic range of 12 to 25 Hz. These long, patterned, infrasonic call series are sometimes referred to as "songs." The short-duration sounds are transient, frequency-modulated calls that have a higher frequency range and shorter duration than song notes and often sweep down in frequency. Short-duration sounds appear to be common; however, they are underrepresented in the literature. These short-duration sounds are <5 sec in duration and are high-intensity, broadband (858±148 Hz) pulses. Source levels of blue whale vocalizations are up to 188 dB re 1 μPa-m. During the Magellan II Sea Test (at-sea exercises designed to test systems for antisubmarine warfare) off the coast of California in 1994, blue whale vocalization source levels at 17 Hz were estimated in the range of 195 dB re 1 μPa-m. Blue whale sounds in the North Atlantic have been confirmed to have different characteristics (i.e., frequency, duration, and repetition) than those recorded in other parts of the world. Blue whales appear to have the highest calling rates when prey was closest to the surface during its vertical migration. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Occurrence in NSWC PCD Study Area **–** There are only two reliable records for blue whales in the GOM; both are strandings. This is one of the rarest cetacean species in the GOM. The blue whale is not expected to occur in the NSWC PCD Study Area.

Bryde's Whale (*Balaenoptera edeni*)

Description **–** The Bryde's whale is a medium-sized baleen whale. Adults can be up to 15.5 m (51 ft) in length, but there is a smaller "dwarf" species that rarely reaches over 10 m (33 ft) in length. Bryde's whales can be easily confused with sei whales; however, closer examination reveals them to have a number of distinctive characteristics. It is not clear how many species of Bryde's whales there are, but genetic analyses suggest the existence of at least two species. The taxonomy of the baleen whale group formerly known as sei and Bryde's whales is currently confused and highly controversial.

Status **–** The best estimate of abundance for Bryde's whales within the Northern GOM Stock is 40, with a minimum population size estimate of 25 whales (Waring et al., 2006). It has been suggested that the Bryde's whales found in the GOM may represent a resident stock, 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).

Distribution **–** The Bryde's whale is found in tropical and subtropical waters, generally not moving poleward of 40° in either hemisphere. In the Atlantic, Bryde's whales are distributed in the Gulf of Mexico and Caribbean Sea south to Cabo Frio, Brazil. Long migrations are not typical of Bryde's whales although limited shifts in distribution toward and away from the equator in winter and summer, respectively, have been observed. Most sightings in the GOM have been made in the DeSoto Canyon region and off western Florida. Additional information on reproductive areas and seasons for this species is not available.

Diving Behavior – Bryde's whales are lunge-feeders, feeding primarily on fish, but they also take small crustaceans. Bryde's whales might dive as long as 20 min.

Acoustics and Hearing **–** Bryde's whales produce low frequency tonal and swept calls similar to those of other rorquals. Calls vary regionally, yet all but one of the call types have a fundamental frequency below 60 Hz. They last from 0.25 sec to several seconds; and they are produced in extended sequences. While no data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Occurrence in NSWC PCD Study Area **–** Bryde's whales found in the GOM may represent a resident stock. Bryde's whales are not frequently sighted in the GOM, although they are observed more frequently than any other species of baleen whale in this region. Nothing is known of their movement patterns in this area, and strandings are scattered throughout the coast of the Gulf. Therefore, there is a low or unknown occurrence of Bryde's whale from the shelf break to the 2,000 m (6,562 ft) isobath throughout most of the NSWC PCD Study Area.

Bryde's whales are expected to occur year-round in an area encompassing the DeSoto Canyon and an area off western Florida, from the shelf break to the 2,000 m (6,562 ft) isobath, based on the fact that most sightings were made in this region during dedicated cetacean surveys. Also considered was the likelihood that Bryde's whale movements are taking place in oceanic waters in this area.

Minke Whale (*Balaenoptera acutorostrata*)

Description **–** The minke whale is the smallest balaenopterid species in the western North Atlantic, with adults reaching lengths of just over 9 m (29.5 ft). The western North Atlantic is important feeding habitat for this species, where minke whales feed primarily on schooling fish such as sand lance, capelin, herring, and mackerel.

Status **–** In the North Atlantic, there are four recognized populations: Canadian East Coast, West Greenland, Central North Atlantic, and Northeastern North Atlantic. Minke whales off the eastern United States are considered to be part of the Canadian East Coast stock, which inhabits the area from the eastern half of the Davis Strait out to 45ºW and south to the Gulf of Maine. The best available abundance estimate for minke whales is 2,998 animals. Minimum population size for the Canadian East Coast stock of minke whales is unknown, but has been estimated at 2,559 individuals (Waring et al., 2007).

Distribution **–** Minke whales are distributed in polar, temperate, and tropical waters. They are less common in the tropics than in cooler waters. This species is most abundant in New England waters rather than the mid-Atlantic. Off eastern North America, the minke whale generally occupies waters over the continental shelf, including inshore bays and estuaries. Minke whales may occur in greater concentrations in the western, northern, and eastern perimeter of the Gulf of Maine, the Bay of Fundy, and along the southern Nova Scotian coast. However, based on whaling catches and surveys worldwide, there is a deep-ocean component to the minke whale's distribution. The southernmost sighting was of one individual offshore of the mouth of the Chesapeake Bay, in waters with a bottom depth of 3,475 m (11,401 ft).

There appears to be a strong seasonal component to minke whale distribution. Spring and summer are periods of relatively widespread and common minke whale occurrence off the northeastern U.S. In the summer months, minke whales occur primarily over the continental shelf and slope in waters from the Bay of Fundy and the Scotian Shelf the to the southern map extent. During fall in New England waters, there are fewer minke whales but during early winter (January and February), the species appears to be largely absent from this area. However, there are occasional observations in the western Gulf of Maine and in waters southeast of Cape Cod. Minke whales off the U.S. Atlantic Coast apparently migrate offshore and southward in winter. Minke whales are known to occur during the winter months (December through March) in the western North Atlantic from Bermuda to the West Indies. There are only stranding records available to indicate minke whale occurrence in the GOM.

Diving Behavior **–** A general surfacing pattern of minke whales has been described, consisting of about four surfacings interspersed by short-duration dives averaging 38 sec. After the fourth surfacing, there was a longer duration dive ranging from approximately 2 to 6 min.

Acoustics and Hearing **–** Recordings of minke whale sounds indicate the production of both high and low-frequency sounds (range: 0.06 to 20 kHz). Minke whale sounds have a dominant frequency range of 0.06 to greater than 12 kHz, depending on sound type. Two basic forms of pulse trains have been identified: a “speed-up” pulse train (dominant frequency range: 0.2 to 0.4 kHz) with individual pulses lasting 40 to 60 msec, and a less common “slow-down” pulse train (dominant frequency range: 50 to 0.35 kHz) lasting for 70 to 140 ms. Source levels for this species have been estimated to range from 151 to 175 dB re 1 µPa-m. Source levels for some minke whale sounds have been calculated to range from 150 to 165 dB re 1 µPa-m. In the Southern Hemisphere, a complex and stereotyped sound sequence was recorded (“star-wars vocalization”) that spanned a frequency range of 50 Hz to 9.4 kHz. Broadband source levels between 150 and 165 dB re 1 µPa-m were calculated. “Boings,” recently confirmed to be produced by minke whales and suggested to be a breeding call, consist of a brief pulse at 1.3 kHz, followed by an amplitude-modulated call with greatest energy at 1.4 kHz, with slight frequency modulation over a duration of 2.5 sec. While no empirical data on hearing ability for this species are available, Ketten (1997) hypothesized that mysticetes have acute infrasonic hearing.

Occurrence in NSWC PCD Study Area **–** There are only stranding records available to indicate minke whale occurrence in the GOM. During fall, winter, and spring, there is a low or unknown occurrence of minke whales east of the Mississippi River Delta from the 30 m (98 ft) isobath and moving into deeper waters. Taken into consideration were the known distribution and seasonality of sighting records along the Atlantic U.S. and in the Caribbean and the seasonality and distribution of stranding records in the GOM. Minke whales have also been detected by passive acoustic means in the southern portion of the western North Atlantic during the fall, winter, and spring. Minke whales are not expected anywhere in the eastern GOM in summer. These whales should occur further north on feeding grounds. Additional information on reproductive areas and seasons for this species is not available.

4.2 ODONTOCETES

The following odontocetes have possible or confirmed occurrence in the GOM.

Sperm Whale (*Physeter macrocephalus*)

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. Sperm whales prey on large mesopelagic squid and other cephalopods as well as demersal fish and occasionally benthic invertebrates.

Status – Sperm whales are classified as endangered under the ESA, although they are globally not in any immediate danger of extinction. They are considered a strategic stock. The sperm whale population in the northern GOM as a stock is considered to be distinct from the U.S. Atlantic stock. Genetic analyses, coda vocalizations, and population structure support this. In the GOM, the best abundance estimate for sperm whales is 1,349, with a minimum population estimate of 1,114. There has been no directed research program on sperm whales in the U.S. since 1970, and information is limited to survey sighting reports, stranding records, and a handful of isolated studies (Lowry et al., 2007). Abundance information, population dynamics, and trends are extremely limited for sperm whale populations in U.S. waters (Lowry et al., 2007).

Distribution – Sperm whales are found from tropical to polar waters in all oceans of the world between approximately 70°N and 70°S. 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°. The thermal limits on female distribution correspond approximately to the 40° parallels (50° in the North Pacific; Whitehead, 2003). Photo-identification data analyzed by Jaquet et al. (2003) revealed that seven female sperm whales moved into the Gulf of California from the Galápagos Islands, traveling up to 3,803 km (2,052 NM); these are among the longest documented movements for female sperm whales.

Sperm whales are the most-frequently sighted whale seaward of the continental shelf off the eastern United States. In Atlantic EEZ waters, sperm whales appear to have a distinctly seasonal distribution. In winter, sperm whales are primarily concentrated east and northeast of Cape Hatteras. However, in spring, the center of concentration shifts northward to off Delaware and Virginia and is generally widespread throughout the central MAB and southern Georges Bank. Summer distribution is similar to spring but also includes the area northeast of Georges Bank and into the Northeast Channel region as well as shelf waters south of New England. Fall sperm whale occurrence is generally south of New England over the continental shelf, with a remaining contingent over the continental shelf break in the MAB. Despite these seasonal shifts in concentration, no movement patterns affect the entire stock. Although concentrations shift depending on the season, sperm whales are generally distributed in Atlantic EEZ waters year-round.

Sperm whales show a strong preference for deep water (from the continental shelf break seaward). Sperm whale concentrations have been correlated with high productivity and steep bottom topography. Off the eastern United States, sperm whales are found in regions of pronounced horizontal temperature gradients, such as along the edges of the Gulf Stream and warm-core rings. In the GOM, the region of the Mississippi River Delta has been recognized for high densities of sperm whales and appears to represent an important calving and nursery area for these animals. 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. 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. 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. Most tagged sperm whales in the GOM show a strong preference for the waters of the continental slope and canyon regions, while several individuals go offshore into waters with a bottom depth greater than 3,000 m (9,843 ft). 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.

Diving Behavior – Sperm whales forage during deep dives that routinely exceed a depth of 400 m (1,312 ft) and 30 min duration. Sperm whales are capable of diving to depths of over 2,000 m (6,56 ft) with durations of over 60 min. Male sperm whales spend up to 83 percent of daylight hours underwater. In contrast, females spend prolonged periods of time at the surface (1 to 5 hours daily) without foraging. An average dive cycle consists of about a 45 min dive with a 9 min surface interval. The average swimming speed is estimated to be 0.7 meters per second (m/sec) (1.6 miles per hour [mi/hr]). Dive descents are about 9 to 11 min at a rate of 1.2 to 1.52 m/sec (2.7 to 3.40 mi/hr), and ascents average 11.8 min at a rate of 1.4 m/sec (3.1 mi/hr).

Acoustics and Hearing **–** Sperm whales typically produce short-duration (<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. 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. Codas are shared between individuals of a social unit and are considered to be primarily for intra-group communication. Recent research in the South Pacific suggests that in breeding areas the majority of codas are produced by mature females. Coda repertoires have also been found to vary geographically and are categorized as dialects, similar to those of killer whales. For example, significant differences in coda repertoire have been observed between sperm whales in the Caribbean and those in the Pacific. 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), and low-frequency (dominant frequencies around 0.5 kHz) with estimated source levels between 140 and 162 dB re 1 μPa-m root mean square (rms) and are hypothesized to function in communication with adults. Source levels from adult sperm whale's highly directional (possible echolocation), short (100 μs) clicks have been estimated up to 236 dB re 1 μPa-m rms. 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. 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. In addition to producing clicks, sperm whales, in some regions like Sri Lanka and the Mediterranean Sea, have been recorded making what are called trumpets at the beginning of dives just before commencing click production.

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. The auditory brainstem response (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.

Occurrence in NSWC PCD Study Area – Sperm whales in the GOM aggregate along the continental slope in or near the perimeter of cyclonic (cold-core) eddies. The area of the Mississippi River Delta might represent an important calving and nursery area for sperm whales. 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.

The sperm whale is expected to occur from the continental shelf break to the 3,000 m (9,843 ft) isobath. There is a concentrated occurrence that encompasses the area off the Mississippi River Delta, and the influences of this river, between the continental shelf break and approximately the 1,000 m (3,281 ft) isobath. This is an area that has been recognized for high densities of sperm whales and represents a habitat where they can be predictably found. Sperm whales in this area appear to have affinity for cyclonic (cold-core) eddies. In fact, the largest numbers of encounters with sperm whales appeared to shift in response to shifts in distribution of eddies.

There is a low or unknown occurrence of sperm whales in waters with a bottom depth greater than 3,000 m (9,843 ft), which reflects the fact that there has been comparatively little survey effort in waters this deep, yet there have been confirmed sightings of sperm whales. Occurrence is assumed to be the same throughout the year. Body sizes for most of the sperm whales seen off the mouth of the Mississippi River range from 7 to 10 m (23 to 32.8 ft), which is a typical size for females and younger animals. The area of the Mississippi River Delta might represent an important calving and nursery area for sperm whales. 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.

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

Description – There are two species of *Kogia*: the pygmy sperm whale and the dwarf sperm whale. They are difficult to distinguish from one another, and sightings of either species are often categorized as *Kogia* species (sp). The difficulty in identifying pygmy and dwarf sperm whales is exacerbated by their avoidance reaction toward ships and change in behavior toward approaching survey aircraft. Based on the cryptic behavior of these species and 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. Pygmy and dwarf sperm whales reach body lengths of around 3 and 2.5 m (9.8 and 8.2 ft), respectively. *Kogia* feed on cephalopods and, less often, on deep-sea fish and shrimp. Zooplankton is likely part of the diet of one or more of the common prey species of *Kogia*.

Status – Total numbers of pygmy sperm whales off the U.S. or Canadian Atlantic coast are unknown, although estimates from selected regions of the habitat do exist for select time periods. Because *Kogia breviceps* and *Kogia sima* are difficult to differentiate, estimated abundances include both species of *Kogia*. The GOM population is provisionally being considered a separate stock for management purposes, although there is currently no information to differentiate this stock from the Atlantic Ocean stock(s). The best abundance estimate for both *Kogia* species in the Western North Atlantic stock is 395, with a minimum population estimate of 285. For pygmy and dwarf sperm whales in the Northern GOM, the best abundance estimate is 742 animals with a minimum population of 584. The western North Atlantic stock of the pygmy sperm whale is a strategic stock because the 1996 to 2000 estimated average annual fishery-related mortality to pygmy sperm whales exceeded PBR.

Distribution – Both *Kogia* species have a worldwide distribution in tropical and temperate waters. In the western Atlantic Ocean, *Kogia* sp. (specifically, the pygmy sperm whale) are documented as far north as the northern Gulf of St. Lawrence, as far south as Colombia (dwarf sperm whale), and as far west as Texas in the GOM. Worldwide, both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope. Data from the GOM suggest that *Kogia* may associate with frontal regions along the shelf break and upper continental slope, since these are areas with high epipelagic zooplankton biomass. A satellite-tagged, rehabilitated pygmy sperm whale released off the Atlantic coast of Florida remained along the continental slope and the western edge of the Gulf Stream during the time of the tag's operation. Dwarf sperm whales may have a more oceanic distribution than pygmy sperm whales and/or dive deeper during feeding bouts, based on hematological and stable-isotope data. Information on the reproductive areas and seasons for these species is not available.

Diving Behavior – Whales of the genus *Kogia* make dives of up to 25 min. Median dive times of around 11 min are documented for *Kogia*. 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.

Acoustics and Hearing – The only sound recordings for the pygmy sperm whale are from a stranded individual that produced echolocation clicks ranging from 60 to 200 kHz, with a dominant frequency of 120 to 130 kHz. Recently, a dwarf sperm whale was recorded producing clicks at 13 to 33 kHz with durations of 0.3 to 0.5 sec. A study completed on a stranded pygmy sperm whale indicated a hearing range of 90 to 150 kHz. No information on sound production or hearing is available for the dwarf sperm whale.

Occurrence in NSWC PCD Study Area – As noted earlier, identification to species for this genus is difficult, particularly at sea. Based on the distribution of the available sighting records and the known preference of both *Kogia* sp. for deep waters, pygmy and dwarf sperm whales are expected to occur between the continental shelf break and the 3,000 m (9,843 ft) isobath. There is a low or unknown occurrence of pygmy and dwarf sperm whales in the very deep waters seaward of the 3,000 m (9,843 ft) isobath.

There is no evidence that *Kogia* sp. regularly occur in continental shelf waters of the GOM. However, there are some sighting records for these species in waters over the continental shelf. Therefore, there is also a low or unknown occurrence of *Kogia* sp. between the 50 m (164 ft) isobath and the continental shelf break. Occurrence is assumed to be the same for all four seasons.

Beaked Whales (Various Species)

Description – Worldwide, there are 20 recognized beaked whale species in five genera (Mead, 2002). There are six species of beaked whales known to occur in the western North Atlantic Ocean: Cuvier's beaked whale (*Ziphius cavirostris*); four members of the genus *Mesoplodon*, Gervais' beaked whale (*M. europaeus*), Blainville's beaked whale (*M. densirostris*), True's (*M. mirus*), and Sowerby's beaked whale (*M. bidens*); and the northern bottlenose whale (*Hyperoodon ampullatus*). In the GOM, four have documented occurrence, including Cuvier's beaked whale and three members of the genus *Mesoplodon* (Gervais', Blainville's, and Sowerby's beaked whales).

Identification of *Mesoplodon* to species is very difficult, and in many cases, *Mesoplodon* and Cuvier's beaked whale (*Ziphius cavirostris*) cannot be distinguished; therefore, sightings of beaked whales (Family Ziphiidae) are identified as *Mesoplodon* sp., Cuvier's beaked whale, or unidentified Ziphiidae. Of the beaked whale species, the Cuvier's beaked whale is the easiest to identify. With the exception of the Cuvier's beaked whale, the aforementioned beaked whale species are nearly indistinguishable at sea. Little is known about the habitat preferences of beaked whales. All species of beaked whales probably feed at or close to the bottom in deep oceanic waters, taking whatever suitable prey they encounter or feeding on whatever species are locally abundant.

Mesoplodon species have maximum reported adult lengths of 6.2 m (20 ft); Blainville's beaked whales are documented to reach a maximum length of around 4.7 m (15 ft); Gervais' beaked whale males reach lengths of at least 4.5 m (15 ft), while females reach at least 5.2 m (17 ft); and Sowerby's beaked whale males and females attain lengths of at least 5.5 and 5.1 m (18 and 17 ft), respectively. 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. Northern bottlenose whales are 7 to 9 m (23.0 to 29.5 ft) in length and have rotund bodies, large bulbous heads, and small, well-defined beaks.

Status – The best abundance estimate for Cuvier's beaked whales in the northern GOM is 95 individuals, with a minimum population estimate for the northern GOM of 65 Cuvier's beaked whales. The total number of Cuvier's beaked whales off the eastern U.S. and Canadian Atlantic coast is unknown, but there have been several estimates of an undifferentiated grouping of beaked whales that includes both *Ziphius* and *Mesoplodon* species (see below). It is not possible to determine the minimum population estimate of only Cuvier's beaked whales. The western North Atlantic stock of both the Cuvier's beaked whale and *Mesoplodon* beaked whales, and all beaked whale stocks in the GOM, are strategic stocks because of uncertainty regarding stock size and evidence of human-induced mortality and serious injury associated with acoustic activities. The best estimate of abundance for undifferentiated beaked whales (*Ziphius* and *Mesoplodon* species) in the Western North Atlantic is 3,513, with a minimum population estimate of 2,154. The best abundance estimate for *Mesoplodon* species in the northern GOM is 106 animals. The minimum population estimate for *Mesoplodon* species in the northern GOM is 76. The total number of northern bottlenose whales off the eastern U.S. coast is unknown.

Distribution – Little is known about beaked whale habitat preferences. World-wide, beaked whales normally inhabit continental slope and deep oceanic waters, normally inhabiting deep ocean waters (below 2,000 m [6,562 ft]) or continental slopes (200 to 2,000 m [656 to 6,562 ft]), and rarely straying over the continental shelf. Predictive modeling based on a habitat characterization study of beaked whales suggests similar distribution patterns for the western North Atlantic region. Distribution of *Mesoplodon* sp. in the North Atlantic may relate to water temperature; the Blainville's beaked whale and Gervais' beaked whale occur in warmer southern waters, in contrast to Sowerby's that are more northern. In the GOM, beaked whales are seen in waters with a bottom depth ranging from 420 to 3,487 m (1,378 to 11,440 ft). In many locales, occurrence patterns have been linked to physical features, in particular, the continental slope, canyons, escarpments, and oceanic islands.

Beaked whale abundance off the eastern United States may be highest in association with the Gulf Stream and the warm-core rings it develops. In summer, the continental shelf break off the northeastern U.S. is primary habitat. Waring et al., (2003) conducted a deepwater survey south of Georges Bank in 2002 and examined fine-scale habitat use by beaked whales. Beaked whales were located in waters characterized by a sea surface temperature of 20.7° to 24.9ºC (69.3 to 76.8ºF) and a bottom depth of 500 to 2,000 m (1,640 to 6,562 ft). Offshore waters beyond the continental slope are not often identified as beaked whale habitat; however, this may be due to a lack of survey effort rather than a reflection of the animals' true habitat. Beaked whale distribution in Northwest Providence Channel (within the Great Bahama Canyon) is stratified. Local scale distribution in the Bahamas might be limited to small areas of suitable habitat, particularly for foraging. In the northern Bahamas, Blainville's beaked whales spend the majority of their time along the canyon wall, where water depth is less than 800 m (2,625 ft), while the Cuvier's beaked whale occurs beyond the 1,000 m (3,281 ft) isobath.

Cuvier's beaked whales are the most widely distributed of the beaked whales and are present in most regions of all major oceans. This species occupies almost all temperate, subtropical, and tropical waters, as well as subpolar and even polar waters in some areas. Along the Atlantic U.S. coast, the Cuvier's beaked whale has been reported from Massachusetts and Rhode Island south to the Florida Keys, the West Indies, and the GOM. Cuvier's and Blainville's beaked whales are generally sighted in waters with a bottom depth greater than 200 m (656 ft) and are frequently recorded at bottom depths greater than 1,000 m (3,281 ft). At oceanic islands, Cuvier's beaked whales may be found in deeper waters than Blainville's beaked whales. Information on reproductive areas and seasons is not available for these species.

The ranges of most mesoplodonts are poorly known. The distribution of these species in the western North Atlantic and GOM are known almost entirely from strandings, and may relate to water temperature. Information on reproductive areas and seasons is not available for these species.

Sowerby's beaked whales and True's beaked whales are the most northerly species, occurring in northern, temperate waters of the North Atlantic; in the GOM it is currently considered extralimital. In the northern region, the Sowerby's beaked whale appears to occur primarily between Labrador and New England. The majority of records for True's beaked whale in the North Atlantic are from the east coast of North America, with most strandings occurring between New Jersey and Maryland. The Sowerby's beaked whale is endemic to the North Atlantic; this is considered to be more of a temperate species. Information on reproductive areas and seasons is not available for these species.

Blainville's and Gervais' beaked whales generally occur in warmer, southern waters. The Blainville's beaked whale is thought to have a continuous distribution throughout the tropical, subtropical, and warm-temperate waters of the world's oceans, occurring occasionally in cold temperate areas. There are occurrence records for the Blainville's beaked whale from Nova Scotia south to Florida, the Bahamas, and the GOM. In the western North Atlantic, this species apparently occurs south of North Carolina; the northernmost records may well be strays carried north by the waters of the Gulf Stream. The Gervais' beaked whale is restricted to warm-temperate and tropical Atlantic waters with records throughout the Caribbean Sea. The northernmost record for Gervais' beaked whale in the western North Atlantic Ocean is from New York State and the southernmost is Trinidad; the vast majority of strandings in the northwest Atlantic occur between North Carolina and Florida. The Gervais' beaked whale is the most frequently-stranded beaked whale in the GOM. Information on reproductive areas and seasons is not available for these species.

***Diving Behavior* –** Dives range from those near the surface where the animals are still visible to long, deep dives. Tagged Cuvier's beaked whale dive durations as long as 87 min and dive depths of up to 1,990 m (6,529 ft) have been recorded. Dive durations for *Mesoplodon* sp. are typically over 20 min. Tagged Blainville's beaked whale dives have been recorded to 1,408 m (4,619 ft) and lasting as long as 54 min. Several aspects of diving have been identified between Cuvier's and Blainville's beaked whales: (1) both may dive 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 are substantially slower than descent rates, while during shorter dives there is no consistent differences; and (3) both may spend prolonged periods of time (66 to 155 min) 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 surface intervals between foraging dives have been recorded as 63 min for Cuvier's beaked whales and 92 min for Blainville's beaked whales.

***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. Whistle frequencies are about 2 to 12 kHz, while pulsed sounds range in frequency from 300 Hz to 135 kHz; however, 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, while pulsed sounds had a narrow peak frequency of 13 to 17 kHz, lasting 15 to 44 sec in duration. Short whistles and chirps from a stranded subadult Blainville's beaked whale ranged in frequency from slightly <1 to almost 6 kHz. Recent studies incorporating digital acoustic recording tags (known commonly as DTAGs) attached to both Blainville's and Cuvier's beaked whales in the Ligurian Sea (arm of the Mediterranean 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. The source levels of the Blainville's beaked whales' clicks were estimated to range from 200 to 220 dB re 1 μPam, while they were 214 dB re 1 μPa-m for the Cuvier's beaked whale.

From anatomical examination of their ears, it is presumed that beaked whales are predominantly adapted to best hear ultrasonic frequencies. 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. The only direct measure of beaked whale hearing is from using auditory evoked potential techniques on a stranded juvenile Gervais' beaked whale. The hearing range was 5 to 80 kHz, with greatest sensitivity at 40 and 80 kHz.

Occurrence in NSWC PCD Study Area – Based on the known preference of beaked whales for deep waters and the distribution of available sighting records for the GOM, beaked whales may be expected to occur throughout the GOM in waters off the continental shelf break in the eastern GOM. Occurrence is assumed to be the same year-round.

Rough-Toothed Dolphin (*Steno bredanensis*)

Description – The rough-toothed dolphin is a relatively robust dolphin that reaches 2.8 m (9.2 ft) in length. Cephalopods and fish, including large fish such as dorado, are prey.

Status – The best estimate of abundance for rough-toothed dolphins is 2,223 in the northern GOM. The minimum population estimate for the same area is 1,595 rough-toothed dolphins. There is no information on stock differentiation for the western North Atlantic stock of this species. There are no abundance estimates available for rough-toothed dolphins off the Atlantic coast of the U.S.

Distribution – Rough-toothed dolphins are found in tropical to warm-temperate waters globally, rarely ranging north of 40°N or south of 35°S. Rough-toothed dolphins occur in low densities throughout the Eastern Tropical Pacific (ETP) where surface water temperatures are generally above 25°C (77°F). This species is not a commonly-encountered species in the areas where it is known to occur. 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 GOM, the West Indies, and along the northeastern coast of South.

The rough-toothed dolphin is regarded as an offshore species that prefers deep waters; however, it can occur in waters with variable bottom depths. In the GOM, the rough-toothed dolphin occurs primarily in the deeper waters off the continental shelf. When stranded and rehabilitated individuals were released with tags off the Atlantic Coast of Florida in March 2005, they moved to waters as deep as 4,000 to 5,000 m (13,123 to 16,404 ft) in bottom depth. The rough-toothed dolphin may regularly frequent coastal waters and areas with shallow bottom depths. Sighting and tagging data indicate the use of continental shelf waters by this species in the northern GOM. Additionally, there are reports of rough-toothed dolphins over the continental shelf in shallow waters around La Gomera, Canary Islands, Puerto Rico and the Virgin Islands, the Bahamas, and in coastal waters off Brazil, including even in a lagoon system. All records for this species for Puerto Rico and the Virgin Islands are in waters on the continental shelf. Rough-toothed dolphins have been sighted on the continental shelf in Ilha Grande Bay (southeastern coast of Brazil), but there has not been much sighting effort in deep waters. Information on reproductive areas and seasons is not available for this species.

Diving Behavior – Rough-toothed dolphins may stay submerged for up to 15 min and are known to dive as deep as 150 m (492 ft).

Acoustics and Hearing **–** The rough-toothed dolphin produces a variety of sounds, including broadband echolocation clicks and whistles. Echolocation clicks (duration <250 microseconds [μsec]) typically have a frequency range of 0.1 to 200 kHz, with a dominant frequency of 25 kHz. Whistles (duration <1 sec) have a wide frequency range of 0.3 to greater than 24 kHz but dominate in the 2 to 14 kHz range. There has been no data collected on rough-toothed dolphin hearing ability. However, odontocetes are generally adapted to hear high frequencies.

Occurrence in NSWC PCD Study Area **–** The rough-toothed dolphin is expected to occur seaward of the continental shelf break to the 3,000 m (9,843 ft) isobath based on the known preference of this species for deep waters and the distribution of available sighting records. There is a low or unknown occurrence of this species in waters with a bottom depth greater than 3,000 m (9,843 ft), based on a very small number of sightings in those waters. There is additionally an area of low or unknown occurrence between the 50 m (164 ft) isobath and the shelf break. Two separate mass strandings of rough-toothed dolphins occurred in the Florida Panhandle during December 1997 and 1998. Four of the stranded dolphins were rehabilitated and released, three with satellite-linked transmitters. Water depth at tracking locations of these individuals averaged 195 m (640 ft). Since the tagged individuals were observed again with wild rough-toothed dolphins off the Florida Panhandle, this suggests a previously undocumented regular occurrence of this species in the northeastern GOM and the possibility of encountering rough-toothed dolphins on the continental shelf.

Bottlenose Dolphin (*Tursiops truncatus*)

Description **–** Bottlenose dolphins (genus *Tursiops*) are large, relatively robust dolphins with striking regional variation in body size; adult body length ranges from 1.9 to 3.8 m (6.2 to 12.5 ft). *Tursiops* are opportunistic feeders, taking a wide variety of fish, cephalopods, and shrimp. *Tursiops* use a wide variety of feeding strategies, including feeding in association with shrimp trawls.

Scientists recognize a nearshore (coastal) and an offshore form of the bottlenose dolphin, which may be distinguished by external morphology, hematology, cranial morphology, diet, and parasite load. There is a clear distinction between the nearshore and offshore form of the bottlenose dolphin in the western North Atlantic, suggesting that the two forms may be eventually considered two different species.

Status **–** The stock structure of bottlenose dolphins off the U.S. Atlantic coast is complex. Based on current information, it is expected that multiple coastal stocks of bottlenose dolphins exist and include year-round residents, seasonal residents, and migratory groups. Seven management units for the coastal bottlenose dolphin along the U.S. Atlantic coast have been identified. The western North Atlantic coastal stock is considered depleted under the MMPA (based on estimates that this stock might have declined by over 50 percent as a result of the 1987 to 1988 die-off) and is therefore a strategic stock.

The best abundance estimate for the western North Atlantic coastal stock located within the South Carolina, Georgia, and Florida management units is 15,620, year-round. In summer, the best abundance estimate of dolphins within the northern migratory management unit is 17,466 animals, with a minimum population estimate of 14,621. In the summer for both the northern and southern NC management units, both estuarine and oceanic, the best abundance estimate is 10,865, with a minimum population estimate of 6,061. In the wintertime, much of these management units mix together. The best abundance estimate in the winter for this mixed management unit is 16,913, with a minimum population estimate of 13,558 dolphins. The combined abundance estimate for the western North Atlantic offshore stock is 81,588 dolphins, with a minimum population estimate of 70,775.

In the northern GOM, there are three coastal stocks; a continental shelf stock; an oceanic stock; and numerous bay, sound, and estuarine stocks. It is believed that many of these different stocks may overlap each other. The best estimate of abundance along the GOM continental shelf and slope is 25,320, with a minimum population estimate of 20,414 bottlenose dolphins.

Distribution **–** The overall range of the common bottlenose dolphin is worldwide in tropical and temperate waters. This species occurs in all three major oceans and many seas. Dolphins of the genus *Tursiops* generally do not range poleward of 45°, except around the United Kingdom and northern Europe. Climate changes can contribute to range extensions as witnessed in association with the 1982/83 El Niño event when the range of some bottlenose dolphins known to the San Diego, California area was extended northward by 600 km (324 NM) to Monterey Bay.

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 GOM, the Caribbean, and southward to Venezuela and Brazil. Bottlenose dolphins off the northeast United States are frequently found over the continental shelf, and especially along the shelf break. Bottlenose dolphins may also be found in very deep waters. The range of the offshore bottlenose dolphin stock may include waters beyond the continental slope, and offshore bottlenose dolphins may move between the Atlantic and the GOM.

North of Cape Hatteras, this species demonstrates a disjunctive distribution, with concentrations of animals nearshore (in embayment and within several kilometers of the shore) and offshore, near the continental shelf margin, from 60 to 200 km (32 to 108 NM) from the coast. There is a migratory component to the bottlenose dolphins occurring north of Cape Hatteras. Water temperature may directly or indirectly affect bottlenose dolphin movements. Water temperature may directly affect movements by acting as a thermal barrier to dolphin movement. Alternatively, water temperature may indirectly affect movements by directly affecting prey movements. The coastal bottlenose dolphin stock off the U.S. Atlantic coast shows a temperature-limited distribution. Sightings of coastal bottlenose dolphins (contrasted with the offshore stock) during Cetacean and Turtle Assessment Program (CETAP) surveys occurred in significantly warmer waters, had a distinct northern boundary to their distribution, and were absent from the Study Area during the winter.

South of Cape Hatteras, the nearshore/offshore distribution pattern is less distinct and there appears to be latitudinal clusters of animal concentration rather than the longitudinally discrete concentration areas found north of Cape Hatteras. It should be noted that there has not been much survey effort south of this area. There is little genetic mixing among management units south of North Carolina, which is in contrast to north of Cape Hatteras. Photo-identification and tagging efforts support the genetic work. Based on photo-identification work, there appears to be generally less movement between areas south of Cape Hatteras along the U.S. Atlantic coast (Urian et al., 1999). At least some of the bottlenose dolphins in North Carolina are resident year-round; this is the northern limit of year-round residency documented for bottlenose dolphin in the western North Atlantic. The longest distance match to date south of Cape Hatteras, North Carolina, is between Jacksonville, Florida, and Murrell's Inlet, South Carolina (approximately 450 km [243 NM]). The coastal form, south of Cape Hatteras, North Carolina, is speculated to range from the coast to 27 km (15 NM) offshore.

The offshore stock is found in waters with a bottom depth greater than 25 m (82 ft) and occurs beyond the continental shelf into continental slope waters in lower densities; greater densities are found along the continental shelf break. Offshore bottlenose dolphins were generally distributed between the 200- and 2,000 m (656.2- and 6,562 ft) isobaths from Cape Hatteras to the eastern end of Georges Bank during CETAP surveys. The mean bottom depth for offshore sightings was 846 m (2,774 ft). Sightings of offshore bottlenose dolphins (contrasted with the nearshore stock) during CETAP surveys were more widely distributed relative to geography and temperature.

Nearshore and offshore bottlenose dolphins overlap spatially, and the nearshore stock appears less restricted in its offshore movements than originally suspected. The area of mixing for the offshore and coastal forms in this area is speculated to be 27 to 81 km (15 to 44 NM) offshore.

The bottlenose dolphin is by far the most widespread and common cetacean in coastal waters of the GOM. Bottlenose dolphins are frequently sighted near the Mississippi River Delta and have even been known to travel several kilometers up the Mississippi River. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior **–** Navy bottlenose dolphins have been trained to reach maximum diving depths of about 300 m (984 ft). The presence of deep-sea fish in the stomachs of some individual offshore bottlenose dolphins suggests that they dive to depths of more than 500 m (1,640 ft). A tagged individual near Bermuda had maximum recorded dives of 600 to 700 m (1,969 to 2,297 ft) and durations of 11 to 12 min. Dive durations up to 15 min have been recorded for trained individuals. Typical dives, however, are more shallow and of a much shorter duration. Data from a tagged individual off Bermuda indicated a possible diel dive cycle (i.e., a regular daily dive cycle) in search of mesopelagic (living at depths between 180 and 900 m [591 and 2,953 ft] prey in the deep scattering layer.

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 kHz and a source level of 218 to 228 dB re 1 µPa-m and 3.4 to 14.5 kHz and 125 to 173 dB re 1 µPa-m, respectively. Whistles are primarily associated with communication and can serve to identify specific individuals (i.e., signature whistles). Up to 52 percent of whistles produced by bottlenose dolphin groups with mother-calf pairs can be classified as signature whistles. Sound production also is influenced by group type (single or multiple individuals), habitat, and behavior. Bray calls (low-frequency vocalizations; majority of energy below 4 kHz), for example, are used when capturing fish, specifically sea trout (*Salmo trutta*) and Atlantic salmon (*Salmo salar*), in some regions (i.e., Moray Firth, Scotland). Additionally, whistle production has been observed to increase while feeding. 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). For example, preliminary research indicates that characteristics of whistles from populations in the northern GOM significantly differ (i.e., in frequency and duration) from those in the western north Atlantic.

Bottlenose dolphins can typically hear within a broad frequency range of 0.04 to 160 kHz. 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. Scientists have reported a range of highest sensitivity between 25 and 70 kHz, with peaks in sensitivity at 25 and 50 kHz. 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. Temporary threshold shifts (TTS) in hearing have been experimentally induced in captive bottlenose dolphins using a variety of noises (i.e., broad-band, pulses). 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 μPa2-s, one-second pulses from 3 to 20 kHz at 192 to 201 dB re 1μPa-m, and octave band noise (4 to 11 kHz) for 50 minutes at 179 dB re 1 μPa-m. 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. Observed changes in behavior were induced with an exposure to a 75 kHz one-second pulse at 178 dB re 1 μPa-m. TTS has been measured to be between 8 and 16 kHz (negligible or absent at higher frequencies) after 30 min of noise exposure (4 to 11 kHz) at 160 dB re 1 μPa-m (Nachtigall et al., 2004).

Occurrence in NSWC PCD Study Area – Based on the distribution of sighting records in the GOM, bottlenose dolphins are expected to occur from the shoreline to the 1,000 m (3,281 ft) isobath. There are concentrated occurrences of bottlenose dolphins from the shore to the 30 m (98 ft) isobath off west-central Florida and from the shore to just seaward of the continental shelf break from Cape San Blas, Florida to the western extent of the map area.

Additionally, bottlenose dolphin occurrence is concentrated in a swath encompassing the shelf break east of Cape San Blas, as well as the Florida Keys. There is a low or unknown occurrence of bottlenose dolphins in waters with a bottom depth greater than 1,000 m (3,281 ft), which takes into consideration that comparatively little survey effort has taken place in deeper waters and also that there is a small possibility of encountering this species in that area. Bottlenose dolphin occurrence in the NSWC PCD Study Area is assumed to be similar throughout the year.

In addition to these stocks, distinct populations of bottlenose dolphins reside in bays and estuaries of the GOM. A resident population exists in SAB, which lies within the NSWC PCD Study Area. The best abundance estimate in the bay is 124 individuals with a minimum population estimate of 79 dolphins (Waring et al., 2007). Additional stocks that occur adjacent to the NSWC PCD Study Area include populations of bottlenose dolphins in Mobile Bay/Bonsecour Bay, Perdido Bay, Pensacola Bay/East Bay, Choctawhatchee Bay, SAB, St. Joseph Bay, and St. Vincent Sound/Apalachicola Bay/St. Georges Sound.

Pantropical and Atlantic Spotted Dolphins (*Stenella attenuata* and *Stenella frontalis*)

Description – The pantropical spotted dolphin is a generally slender dolphin. Adults may reach up to 2.6 m (8.5 ft) in length. Pantropical spotted dolphins are born spotless and develop spots as they age although the degree of spotting varies geographically. Some populations may be virtually unspotted. Pantropical spotted dolphins prey on epipelagic fish, squid, and crustaceans, with some take of mesopelagic animals.

The Atlantic spotted dolphin tends to resemble the bottlenose dolphin more than it does the pantropical spotted dolphin. In body shape, it is somewhat intermediate between the two, with a moderately long but rather thick beak. Adults are up to 2.3 m (7.5 ft) long and 143 kilogram (kg) (315 pounds [lb]) in weight. Atlantic spotted dolphins are born spotless and develop spots as they age. Some Atlantic spotted dolphin individuals become so heavily spotted that the dark cape and spinal blaze are difficult to see. There is marked regional variation in adult body size of the Atlantic spotted dolphin. 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. The largest body size is exhibited by the coastal form, which occurs in waters over the continental shelf of North America (U.S. East Coast, GOM, and Central America). The smallest Atlantic spotted dolphins are those around oceanic islands, such as the Azores, and on the high seas in the western North Atlantic. Atlantic spotted dolphins feed on small cephalopods, fish, and benthic invertebrates, and in the GOM have been seen feeding cooperatively and are known to feed in association with shrimp trawls.

Prior to 1998, sightings of the Atlantic spotted dolphin and the pantropical spotted dolphin in U.S. Atlantic waters were not always differentiated due to difficulty in distinguishing the two species at sea. The two species are still difficult to distinguish from one another in the field.

Status – The best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins. In the North Atlantic, the best abundance estimate is 50,978, with a minimum population estimate (based on the combined offshore and coastal abundance estimates) of 36,235. The northern GOM population was recently confirmed to be genetically differentiated from the western North Atlantic populations.

The pantropical spotted dolphin is the most abundant and commonly-seen cetacean in deep waters of the northern GOM. The best estimate of abundance for pantropical spotted dolphins in the northern GOM is 91,321, with a minimum population of 79,879 dolphins. In the western North Atlantic, the best estimate of abundance for pantropical spotted dolphins is 4,439 with a minimum population estimate of 3,010 (Waring et al., 2006).

Distribution – The pantropical spotted dolphin is distributed in tropical and subtropical waters worldwide, generally occurring in oceanic waters beyond the shelf break. *Stenellid* dolphins have been sighted within the Gulf Stream, which is consistent with the oceanic distribution of pantropical spotted dolphins and their preference for warm waters. Pantropical spotted dolphins in the GOM have been sighted in waters with bottom depths ranging from 435 to 2,121 m (1,427 to 6,959 ft). Pantropical spotted dolphins in the GOM do not appear to have a preference for any one specific habitat type (i.e., within the Loop Current, inside cold-core eddies, or along the continental slope).

The Atlantic spotted dolphin, as its name suggests, is endemic to the tropical and warm-temperate species. In the western North Atlantic, this translates to waters from northern New England to the GOM and the Caribbean, and southward to the coast of Venezuela. Known densities of Atlantic spotted dolphins are highest in the eastern GOM, east of Mobile Bay. The large, heavily spotted coastal form of the Atlantic spotted dolphin typically occurs over the continental shelf inside or near the 185 m (607 ft) isobath, usually at least 8 to 20 km (4 to 11 NM) offshore. Sightings of offshore spotted dolphins have been made along the north wall of the Gulf Stream and warm-core ring features. Additional information on reproductive areas and seasons is not available for this species.

***Diving Behavior* –** Pantropical spotted dolphins dives during the day are generally shorter and shallower than dives at night; rates of descent and ascent are higher at night than during the day. Similar mean dive durations and depths have been obtained for tagged pantropical spotted dolphins in the ETP and off Hawaii. The only information on dive depth for Atlantic spotted dolphins is based on a satellite-tagged individual from the GOM. This individual made short, shallow dives (over 76 percent of the time to depths less than 10 m [33 ft]) over the continental shelf, although some dives were as deep as 40 to 60 m (131 to 197 ft).

***Acoustics and Hearing* –** Pantropical spotted dolphin whistles have a frequency range of 3.1 to 21.4 kHz. 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. 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 (<100 kHz).

A variety of sounds including whistles, echolocation clicks, squawks, barks, growls, and chirps have been recorded for the Atlantic spotted dolphin. 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. Other sounds, such as squawks, barks, growls, and chirps, typically range in frequency from 0.1 to 8 kHz. 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. Echolocation click source levels as high as 210 dB re 1 μPa-m peak-to-peak have been recorded. There are no empirical hearing data for Atlantic spotted dolphins.

***Occurrence in NSWC PCD Study Area* –** The Atlantic spotted dolphin is expected to occur in waters over the continental shelf in the GOM from the 10 m (33 ft) isobath to the shelf break. The majority of the sightings support this determination. Taking into consideration sightings recorded seaward of the continental shelf break and over the continental slope near the Mississippi River Delta and in the southern GOM, there is a low or unknown occurrence of this species between the shelf break and the 2,000 m (6,562 ft) isobath. Occurrence is assumed to be similar during all seasons.

The pantropical spotted dolphin is an oceanic species and is the most common cetacean in the oceanic northern GOM and is found in the deeper waters off the continental shelf. The pantropical spotted dolphin is expected to occur from the continental shelf break to the 3,000 m (9,843 ft) isobath. There is a low or unknown occurrence of the pantropical spotted dolphin seaward of the 3,000 m (9,843 ft) isobath based on the little survey effort in waters this deep compared to the waters off the shelf break and over the continental slope. Occurrence is assumed to be similar throughout the year.

Spinner Dolphin (*Stenella longirostris*)

Description – This is a very slender dolphin that has a very long and slender beak and can reach lengths of 2.4 m (7.9 ft). This species has a three-part color pattern (dark gray cape, light gray sides, and white belly). There are four known subspecies of spinner dolphins and probably other undescribed ones. Spinner dolphins feed primarily on small mesopelagic fish, squid, and sergestid shrimp, diving to at least 200 to 300 m (656 to 984 ft). Many of these organisms become available to spinner dolphins when the deep-scattering layer moves toward the surface at night.

Status – The best estimate of abundance for spinner dolphins in the northern GOM is 11,971. The minimum population estimate for the northern GOM is 6,990 spinner dolphins. Population size in the western North Atlantic is unknown (Waring et al., 2006).

Distribution – The spinner dolphin is found in tropical and subtropical waters worldwide, occurring in both coastal and oceanic environments. Limits are near 40ºN and 40ºS. In the western North Atlantic, they are known from South Carolina to Florida, the Caribbean, the GOM, and the West Indies southward to Venezuela. Sightings of this species off the U.S. Atlantic coast and GOM have occurred primarily in deeper waters (bottom depth greater than 2,000 m [6,562 ft]). Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – Spinner dolphins feed primarily on small mesopelagic fish, squid, and sergestid shrimp, and they dive to at least 199 to 300 m (653 to 984 ft). Foraging takes place primarily at night when the mesopelagic prey migrates vertically towards the surface and also horizontally towards the shore. 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. 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. 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. Clicks have a dominant frequency of 60 kHz. The burst pulses are predominantly ultrasonic, often with little or no energy below 20 kHz. Source levels between 195 and 222 dB re 1 µPa-m have been recorded for spinner dolphin clicks. Other research indicates that this species produces whistles in the range of 1 to 22.5 kHz with the dominant frequency being 6.8 to 17.9 kHz, although their full range of hearing may extend down to 1 kHz or below as reported for other small odontocetes (Nedwell et al., 2004).

Occurrence in NSWC PCD Study Area – As a species with a preference for deep waters, the spinner dolphin is expected to occur from the continental shelf break to the 2,000 m (6,562 ft) isobath. There is a low or unknown occurrence of the spinner dolphin seaward of the 2,000 m (6,562 ft) isobath. Occurrence is assumed to be similar throughout the year.

Clymene Dolphin (*Stenella clymene*)

Description – The Clymene dolphin is easily confused with the spinner dolphin (and the short-beaked common dolphin) due to its similar appearance. The Clymene dolphin, however, is smaller and more robust, with a much shorter and stockier beak. The Clymene dolphin can reach at least 2 m (7 ft) in length and weights of at least 85 kg (187 lb). Available information on feeding habits is limited to the stomach contents of two individuals and one observation of free-ranging dolphins; Clymene dolphins feed on small fish and squid.

Status – For animals in the GOM, the best estimate of abundance for Clymene's dolphins is 17,355, with a minimum population estimate of 10,528 dolphins. 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.

Distribution – The Clymene dolphin is known only from the tropical and subtropical Atlantic Ocean, primarily sighted in deep waters well beyond the edge of the continental shelf. Biogeographically, the Clymene dolphin is found in the warmer waters of the North Atlantic from the North Equatorial Current, the Gulf Stream, and the Canary Current. These records suggest that, in the mid-Atlantic off the U.S., the warm waters of the Gulf Stream influence Clymene dolphin distribution. In a study of habitat preferences in the GOM, Clymene dolphins were found more often on the lower slope and deep water areas in regions of cyclonic or confluence circulation. Clymene dolphins are found in deep waters with a mean bottom depth of 1,870 m (6,135 ft). Additional information on reproductive areas and seasons is not available for this species.

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

Occurrence in NSWC PCD Study Area – Based on the distribution of sighting records, the Clymene dolphin is expected to occur from the continental shelf break to the 3,000 m (9,843 ft) isobath. There has not been much survey effort in waters deeper than 3,000 m (9,843 ft), yet there are documented sightings seaward of the 3,000 m (9,843 ft) isobath. Therefore, there is a low or unknown occurrence of the Clymene dolphin seaward of the 3,000 m (9,843 ft) isobath. Occurrence is assumed to be the same during all seasons.

Striped Dolphin (*Stenella coeruleoalba*)

Description – The striped dolphin is a uniquely marked dolphin, which is relatively robust and reaches 2.6 m (8.5 ft) in length. Striped dolphins often feed in pelagic or benthopelagic zones along or seaward of the continental slope. Small, midwater fish (in particular, myctophids or lanternfish) and squid are the dominant prey.

Status – The best abundance estimate for striped dolphins in the northern GOM is 6,505, with a minimum population estimate of 4,599 striped dolphins (Waring et al., 2006).

Distribution – The striped dolphin has a worldwide distribution in cool-temperate to tropical waters. In the western North Atlantic, this species is known from Nova Scotia southward to the Caribbean, the GOM, and Brazil. Striped dolphins are usually found outside the continental shelf, typically over the continental slope out to oceanic waters, often associated with convergence zones and waters influenced by upwelling. This species appears to avoid waters with sea temperatures of less than 20°C (68°F). Additional information on reproductive areas and seasons is not available for this species.

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 possesses 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. 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. 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.

Occurrence in NSWC PCD Study Area – The striped dolphin is expected to occur from the continental shelf break to the 2,000 m (6,562 ft) isobath. There are a few confirmed sightings of striped dolphins seaward of the 2,000 m (6,562 ft) isobath; therefore, there is a low or unknown occurrence of striped dolphins in waters with a bottom depth greater than 2,000 m (6,562 ft). Occurrence is assumed to be the same throughout the year.

Fraser's Dolphin (*Lagenodelphis hosei*)

Description – The Fraser's dolphin reaches a maximum length of 2.7 m (8.9 ft) and is generally more robust than other small delphinids. Fraser's dolphins feed on midwater fish, squid, and shrimp.

Status – The best estimate of abundance for Fraser's dolphins in the northern GOM is 726, with a minimum population estimate of 427 animals. The population size of Fraser's dolphins off the U.S. or Canadian Atlantic coast is unknown. Present data is not sufficient to calculate a minimum population estimate for this stock (Waring et al., 2006).

Distribution – Fraser's dolphin is found in tropical and subtropical waters around the world, typically between 30ºN and 30ºS. Strandings in temperate areas are considered extralimital and usually are associated with anomalously warm water temperatures. This is an oceanic species except in places where deep water approaches the coast. Few records exist of this species from the Atlantic Ocean. In the GOM, this species occurs mostly in very deep waters well beyond the continental shelf break. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – There is no information available on depths to which Fraser's dolphins may dive, but they are thought to be capable of deep diving.

Acoustics and Hearing – Very little is known of the acoustic abilities of the Fraser's dolphin. Fraser's dolphin whistles have a frequency range of 7.6 to 13.4 kHz. There are no hearing data for this species.

Occurrence in NSWC PCD Study Area – Fraser's dolphin occurrence is assumed to be the same for all four seasons in the eastern GOM, and is expected to occur from the continental shelf break to the 3,000 m (9,843 ft) isobath. This determination was based on the distribution of sightings in the NSWC PCD Study Area and the known habitat preferences of this species. Fraser's dolphins have been sighted over the abyssal plain in the southern GOM. There is a low or unknown occurrence of the Fraser's dolphin seaward of the 3,000 m (9,843 ft) isobath.

Risso's Dolphin (*Grampus griseus*)

Description – The Risso's dolphin is a moderately large, robust animal reaching at least 3.8 m (12.5 ft) in length. Adults range from dark gray to nearly white and are heavily covered with white scratches and splotches. Cephalopods are the primary prey.

Status – The best abundance estimate for Risso's dolphins in the western North Atlantic is 20,479. The minimum population estimate is 12,920 animals (Waring et al., 2007). The best estimate of abundance for Risso's dolphins in the northern GOM is 2,169, with a minimum population estimate of 1,668 dolphins (Waring et al., 2006).

Distribution – The Risso's dolphin is distributed worldwide in tropical and warm-temperate waters, roughly between 60ºN and 60ºS, where surface water temperature is usually greater than 10 degrees Celsius (ºC) (50 degrees Fahrenheit [°F]). In the western North Atlantic, this species is found from Newfoundland southward to the GOM, throughout the Caribbean, and around the equator. A number of studies have noted that the Risso's dolphin is found along the continental slope. The strong correlation between the Risso's dolphin distribution and the steeper portions of the upper continental slope in the GOM is most likely the result of cephalopod distribution in the same area. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – Individuals may remain submerged on dives for up to 30 min and dive as deep as 600 m.

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. The combined whistle and burst pulse sound (2 to 22 kHz, mean duration of 8 sec) appears to be unique to Risso's dolphin. 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.

Baseline research on the hearing ability of this species was conducted 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. Hearing in a stranded infant has also been measured. 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.

Occurrence in NSWC PCD Study Area **–** The Risso's dolphin is most commonly found in areas with steep bottom topography. Based on this known habitat preference and the distribution of sighting records in the northern GOM, Risso's dolphins are expected to occur between the continental shelf break and the 2,000 m (6,562 ft) isobath throughout the year. There is a concentrated occurrence of the Risso's dolphin south of the Mississippi River Delta to approximately where the DeSoto Canyon begins, from the shelf break to the vicinity of the 1,000 m (3,281 ft) isobath. This is based on sighting concentrations, as well as the oceanography of the area being favorable to prey concentrations for this species. There is a low or unknown occurrence of this species in waters beyond the 2,000 m (6,562 ft) isobath.

Melon-Headed Whale (*Peponocephala electra*)

Description **–** Melon-headed whales at sea closely resemble pygmy killer whales. Melon-headed whales reach a maximum length of 2.75 m (9 ft). Melon-headed whales prey on squid, pelagic fish, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic species found in waters up to 1,500 m (4,921 ft) deep, suggesting that feeding takes place deep in the water column.

Status **–** The best estimate of abundance for melon-headed whales in the northern GOM is 3,451, with a minimum population estimate of 2,238 melon-headed whales (Waring et al., 2006).

Distribution **–** Melon-headed whales are found worldwide in deep tropical and subtropical waters. Maryland is thought to represent the extreme of the northern distribution for this species in the northwest Atlantic. There are very few records for melon-headed whales in the North Atlantic. Little information is available on habitat preferences for this species. Most melon-headed whale sightings in the GOM have been in deep waters, well beyond the edge of the continental shelf and waters out over the abyssal plain. A group of melon-headed whales and Fraser's dolphins was sighted in waters east of Cape Hatteras, North Carolina, with a bottom depth of 3,000 m (9,843 ft). Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – There is no diving information available for this species. Melon-headed whales prey on squid, pelagic fish, and occasionally crustaceans. Most of the fish and squid families eaten by this species consist of mesopelagic species found in waters up to 1,500 m (4,921 ft) deep, suggesting that feeding takes place deep in the water column.

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

Occurrence in NSWC PCD Study Area **–** Melon-headed whales and pygmy killer 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. Based on known preferences of the melon-headed whale for deep waters and the confirmed sightings of this species in the GOM, melon-headed whales are expected to occur between the continental shelf break and the 3,000 m (9,843 ft) isobath. There is a low or unknown occurrence of melon-headed whales in waters with a bottom depth greater than 3,000 m (9,843 ft) based on the few available sighting records. Melon-headed whale occurrence patterns are expected to be the same year-round in the eastern GOM.

Pygmy Killer Whale (*Feresa attenuata*)

Description **–** 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 rounded flipper shape is the best distinguishing characteristic of a pygmy killer whale. Pygmy killer whales reach lengths of up to 2.6 m (8.5 ft). Pygmy killer whales eat mostly fish and squid, and sometimes attack other dolphins.

Status **–** The best estimate of abundance for pygmy killer whales in the northern GOM is 408. The minimum population estimate for the northern GOM is 256 pygmy killer whales.

Distribution **–** This species has a worldwide distribution in deep tropical, subtropical, and warm temperate oceans. Pygmy killer whales generally do not range north of 40ºN or south of 35ºS. The sparse number of pygmy killer whale sightings might be due to its somewhat cryptic behavior. The pygmy killer whale is a deepwater species, with a possible occurrence most likely in waters outside the continental shelf break. This species does not appear to be common in the GOM. In the northern GOM, the pygmy killer whale is found primarily in deeper waters beyond the continental shelf extending out to waters over the abyssal plain.

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. 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. These clicks possess characteristics of echolocation clicks. There are no hearing data available for this species.

Occurrence in NSWC PCD Study Area – 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. Based on confirmed sightings of the pygmy killer whale in the GOM and this species' propensity for deeper water, pygmy killer whales are expected to occur between the continental shelf break and the 3,000 m (9,843 ft) isobath. There is a low or unknown occurrence of pygmy killer whales in waters with a bottom depth greater than 3,000 m (9,843 ft) based on the few available sighting records. Pygmy killer whales are thought to occur year-round in the GOM in small numbers and occurrence patterns are expected to be the same year-round. Additional information on reproductive areas and seasons is not available for this species.

False Killer Whale (*Pseudorca crassidens*)

Description – The false killer whale is a large, dark gray to black dolphin reaching lengths of 6.1 m (20.0 ft). The flippers have a characteristic hump on the leading edge; this is perhaps the best characteristic in distinguishing this species from the other "blackfish" (pygmy killer, melon-headed, and pilot whales).

Status – The best estimate of abundance for false killer whales in the northern GOM is 1,038. The minimum population estimate for the northern GOM is 606 false killer whales (Waring et al., 2006).

Distribution – False killer whales are found in tropical and temperate waters, generally between 50ºS and 50ºN with a few records north of 50ºN in the Pacific and the Atlantic. This species is found primarily in oceanic and offshore areas, though they do approach close to shore at oceanic islands. Inshore movements are occasionally associated with movements of prey and shoreward flooding of warm ocean currents. In the western North Atlantic, false killer whales have been reported off Maryland southward along the mainland coasts of North America, the GOM, and the southeastern Caribbean Sea. Although sample sizes are small, most false killer whale sightings in the GOM are east of the Mississippi River, and sightings of this species in the northern GOM occur in oceanic waters greater than 200 m (656 ft) deep. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – There is no diving information available for this species. However, it is known that false killer whales primarily eat deep-sea cephalopods and fish, and have been known to attack other toothed whales, including sperm whales and baleen whales. False killer whales in many different regions are known to take tuna from long-lines worldwide.

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. Click source levels typically range from 200 to 228 dB re 1 μPa-m. 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. False killer whales can hear frequencies ranging from approximately 2 to 115 kHz with best hearing sensitivity ranging from 16 to 64 kHz. 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, peaking at 22.5 kHz.

Occurrence in NSWC PCD Study Area – Most sightings of false killer whales in the GOM have been made in oceanic waters with a bottom depth greater than 200 m (656 ft); there also have been sightings from over the continental shelf. False killer whales are expected to occur between the continental shelf break and the 2,000 m (6,562 ft) isobath throughout the GOM. There is a low or unknown occurrence of this species seaward of the 2,000 m (6,562 ft) isobath, which is based on the sighting records. There is also a low or unknown occurrence of false killer whales between the 50 m (164 ft) isobath and the shelf break in the NSWC PCD Study Area. This was based on the fact that false killer whales sometimes make their way into shallower waters, such as off Hong Kong and in the GOM, as well as 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. There have been occasional reports of fish stealing by these animals (the false killer whale frequently has been implicated in such fishery interactions). False killer whale occurrence patterns in the eastern GOM are expected to be the same throughout the year.

Killer Whale (*Orcinus orca*)

Description – The killer whale is the largest member of the dolphin family; females may reach 7.7 m (25.3 ft) in length and males 9.0 m (29.5 ft). The black-and-white color pattern of this species is striking as is the tall, erect dorsal fin of the adult male (1.0 to 1.8 m in height [3.3 to 5.9 ft]). Killer whales feed on bony fish, elasmobranchs, cephalopods, seabirds, sea turtles, and other marine mammals.

Status – The best estimate of abundance for killer whales in the northern GOM is 133, with a minimum population estimate of 90 (Waring et al., 2006).

Distribution – This is a cosmopolitan species found throughout all oceans and contiguous seas, from equatorial regions to the polar pack ice zones. Although found in tropical waters and the open ocean, killer whales as a species are most numerous in coastal waters and at higher latitudes. Killer whales have the most ubiquitous distribution of any species of marine mammal, and they have been observed in virtually every marine habitat from the tropics to the poles and from shallow, inshore waters (and even rivers) to deep, oceanic regions. In coastal areas, killer whales often enter shallow bays, estuaries, and river mouths. Based on a review of historical sighting and whaling records, killer whales in the northwestern Atlantic are found most often along the shelf break and further offshore.

In the western North Atlantic, killer whales are known from the polar pack ice southward to Florida, the Lesser Antilles, and the GOM. Killer whales are sighted year-round in the northern GOM. It is not known whether killer whales in the GOM stay within the confines of the GOM or range more widely into the Caribbean and adjacent North Atlantic Ocean. Little is known of the movement patterns of killer whales in this region. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – The maximum depth recorded for free-ranging killer whales diving off British Columbia is 264 m (866 ft). On average, however, for seven tagged individuals, less than 1 percent of all dives examined were to depths greater than 30 m (98 ft). A trained killer whale dove to a maximum of 260 m (853 ft). The longest duration of a recorded dive from a radio-tagged killer whale was 17 min.

Acoustics and Hearing **–** Killer whales produce a wide-variety of clicks and whistles, but most of this species' social sounds are pulsed, with frequencies ranging from 0.5 to 25 kHz (dominant frequency range: 1 to 6 kHz). Echolocation clicks recorded for this species indicate source levels ranging from 195 to 224 dB re 1 μPa-m peak-to-peak, dominant frequencies ranging from 20 to 60 kHz, and durations of 80 to 120 μs. Source levels associated with social sounds have been calculated to range from 131 to 168 dB re 1 μPa-m and have been demonstrated to vary with vocalization type (e.g., whistles: average source level of 140.2 dB re 1 μPa-m, variable calls: average source level of 146.6 dB re 1 μPa-m, and stereotyped calls: average source level 152.6 dB re 1 μPa-m). Additionally, killer whales modify their vocalizations depending on social context or ecological function (i.e., short-range vocalizations [<10 km, or 6.2 mile, range]) are typically associated with social and resting behaviors and long-range vocalizations [10 to 16 km, or 6.2 to 9.9 mile, range] associated with travel and foraging.

Acoustic studies of resident killer whales in British Columbia have found that they possess dialects, which are highly stereotyped, repetitive discrete calls that are group-specific and are shared by all group members. These dialects are likely used to maintain group identity and cohesion and may serve as indicators of relatedness that help in the avoidance of inbreeding between closely related whales. Dialects have been documented in northern Norway and southern Alaskan killer whales populations and likely occur in other regions as well. Both behavioral and ABR techniques indicate killer whales can hear a frequency range of 1 to 100 kHz and are most sensitive at 20 kHz, which is one the lowest maximum-sensitivity frequency known among toothed whales.

Occurrence in NSWC PCD Study Area **–** Killer whale sightings in the northern GOM are generally clumped in a broad region south of the Mississippi River Delta and in waters ranging in bottom depth from 256 to 2,652 m (840 to 8,701 ft). Based on this information, killer whales are expected to occur in an area south of the Mississippi River Delta from the shelf break into waters with an approximate bottom depth of 2,000 m (6,562 ft). Sightings have been made in waters over the continental shelf (including close to shore) as well as in waters past the 2,000 m (6,562 ft) isobath. There is a low or unknown possibility of encountering killer whales anywhere in the GOM (besides the before-mentioned area of expected occurrence) shoreward of the 10 m (33 ft) isobath. Occurrence patterns are assumed to be similar for all seasons.

Long-Finned and Short-Finned Pilot Whales (*Globicephala* sp.)

Description **–** Pilot whales are among the largest members of the dolphin family. The long-finned pilot whale (*Globicephala melas*) may reach 5.7 m (18.7 ft) (females) and 6.7 m

(22 ft) (males) in length, whereas the short-finned pilot whale (*G. macrorhynchus*) may attain lengths of 5.5 m (18 ft) (females) and 6.1 m (20 ft) (males).

Distinguishing between the two species of pilot whales is difficult in the field. As the names imply, proportional flipper lengths in the two species generally differ. In long-finned pilot whales, the flippers are generally 20 percent of the total body length. In short-finned pilot whales, the flippers are typically about 17 percent of the total body length. Both pilot whale species feed primarily on squid but also take fish.

***Status* –** For short-finned pilot whales in the GOM, the best estimate of abundance is 2,388, with a minimum population estimate of 1,628 animals (Waring et al., 2006). Long-finned pilot whales are considered extralimital in the GOM.

***Distribution* –** Long-finned pilot whales occur in temperate and subpolar waters. The short-finned pilot whale is found worldwide in tropical and warm-temperate seas, generally in deep offshore areas. The short-finned pilot whale usually does not range north of 50ºN or south of 40ºS. The apparent ranges of the two pilot whale species overlap in shelf/shelf-edge and slope waters of the northeastern United States between 35ºN and 38º to 39ºN (or from New Jersey to Cape Hatteras, North Carolina).

Pilot whales are found in both nearshore and offshore environments. Pilot whales are found over the continental shelf break, in slope waters, and in areas of high topographic relief. Pilot whales are sometimes seen in waters over the continental shelf. A number of studies have found the distribution and movements of pilot whales to coincide closely with the abundance of squid. The occurrence of pilot whales in the Southern California Bight was found to be associated with high relief topography, which has been related to the squid-feeding habits of pilot whales. This is likely the case in other geographic locations. Only the short-finned pilot whale is known in the GOM. Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – Pilot whales are deep divers; foraging dives deeper than 600 m (1,969 ft) are recorded. Pilot whales are able to stay submerged for up to 40 min.

***Acoustics and Hearing* –** 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. There are no hearing data available for either pilot whale species.

***Occurrence in NSWC PCD Study Area* –** 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. There are no confirmed records of long-finned pilot whales in the GOM. 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.

Based on sightings and the apparent preference of pilot whales for steep bottom topography, this species is expected to occur from the continental shelf break to the 2,000 m (6,562 ft) isobath in the NSWC PCD Study Area. There is a low or unknown occurrence of pilot whales between the 10 m (33 ft) isobath and the shelf break, east of Cape San Blas, Florida, past the Florida Keys. There is a low or unknown occurrence of pilot whales between the 2,000 and 3,000 m

(6,562- and 9,843 ft) isobath. Pilot whales do have an oceanic distribution, and the few shipboard surveys that have occurred past the 2,000 m (6,562 ft) isobath have occasionally recorded pilot whales.

There is a preponderance of pilot whale sightings in the historical records for the northern GOM. Pilot whales, however, are less often reported during recent surveys, such as GulfCet (DON, 2007). The reason for this apparent decline is not known, but it has been suggested that abundance or distribution patterns might have changed over the past few decades, perhaps due to changes in available prey species. Occurrence patterns are assumed to be the same throughout the year.

4.3 SIRENIAN

The following sirenian has confirmed occurrence in the GOM.

West Indian Manatee (*Trichechus manatus*)

Description – There are two geographically separated subspecies of West Indian manatee: the Florida manatee (*Trichechus manatus latirostris*) and the Antillean manatee (*Trichechus manatus manatus*). The manatee is a rotund, slow-moving animal, which reaches a maximum length of 3.9 m (13 ft). The manatee has a small head, a squarish snout with fleshy mobile lips, and two semicircular nostrils at the front. The tail is horizontal and rounded. The body is gray or gray-brown and covered with fine hairs that are sparsely distributed. The back is often covered with distinctive scars from boat propeller cuts. Manatees are predominantly herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation, but they also preferentially ingest invertebrates.

Status – The Florida Fish and Wildlife Conservation Commission (FWC) coordinates a series of aerial surveys and ground counts one to three times each winter in Florida to determine the number of manatees statewide (USFWS, 2007a). The best, current, minimum population estimate of the statewide manatee population is approximately 3,300 animals based on a single statewide count at warm-water refuges and adjacent areas in January 2001 (USFWS, 2007a). In the most recent revision of the manatee recovery plan, it was concluded that based on data on manatee movement patterns, Florida manatees should be divided into four relatively discrete management units or subpopulations, each representing a significant portion of the species' range.

West Indian manatees are currently classified as endangered under the ESA, and are therefore considered depleted under the MMPA. The U.S. Fish and Wildlife Service (USFWS) recently concluded the overall population of the Florida Manatee has increased and the Antillean manatee levels are stable, and neither subspecies is currently in danger of becoming extinct within all or a significant portion of their range. As, such, the USFWS has recently recommended that this species be reclassified from endangered to threatened (USFWS, 2007a).

Several different mathematical models have been created in an attempt to model the dynamics of Florida manatee populations (Runge et al. 2007). One model, the manatee core biological model, was developed to forecast population dynamics and describe the life history of the

Florida manatee in four separate regions of Florida (Atlantic, Southwest, Upper St. Johns and Northwest) (Runge et al. 2007). This model found that under current levels of threats, including the anticipated loss of warm-water, the statewide manatee population has a low probability of extinction and a substantial shift in the regional distribution of manatees within the state is likely (Runge et al. 2007).

In 1976, critical habitat was designated for the manatee in Florida. The designated area included all of the manatee's known range at that time (including waterways throughout about one-third to one-half of Florida). This critical habitat designation has been infrequently used or referenced since it is broad in description, treats all waterways the same, and does not highlight any particular areas. There are two types of manatee protection areas in the state of Florida: manatee sanctuaries and manatee refuges. Manatee sanctuaries are areas where all waterborne activities are prohibited while manatee refuges are areas where activities are permitted but certain waterborne activities may be regulated.

***Distribution* –** West Indian manatees occur in warm, subtropical and tropical waters of the western North Atlantic from the southeastern United States to Central and northern South America, the Caribbean, and the West Indies, primarily in freshwater systems, estuaries, and shallow, nearshore, coastal waters. Manatees occur along both the Atlantic and Gulf coasts of Florida. Manatees are sometimes reported in the Florida Keys; these sightings are typically in the upper Florida Keys, with some reports as far south as Key West. Manatees along the Atlantic coast exhibit several different patterns of seasonal movement, ranging from year-round residents to long-distance migrants. Manatees have been found to be highly consistent in their seasonal movement patterns over time and showed strong fidelity to warm season and winter ranges both within and across years. Historically, manatees were probably restricted to southernmost Florida during the winter, expanding their distribution northward in the summer. Industrial development has created warm-water refuges (e.g., power plant effluent plumes) for the manatee, even in winter, while the introduction of several exotic aquatic plant species expanded the available food supply; both factors enabled the manatee population to expand its winter range. The Wakulla River is the northern limit of the manatee's typical warm-season range on the Gulf Coast.

Sightings of manatees are usually restricted to warm freshwater, estuarine, and extremely nearshore coastal waters. Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats. Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, mating, and calving. Estuarine and brackish waters and natural and artificial freshwater sources are sought by manatees. A biological status review of the Florida manatee was completed in April 2006. In this report, the extent of occurrence of this species included all areas within large bays, estuaries, and rivers plus remaining areas lying between the shoreline and the 3.7 m (12 ft) depth contour for the entire State of Florida (Haubold et al., 2006). The report indicated the Florida manatee can occur in waters deeper than 3.7 m (12 ft), but survey data suggests the majority of this species occurs in relatively shallow waters (Haubold et al., 2006). However, although manatees are expected to inhabit nearshore areas, some have been sighted offshore as well, indicating that some individuals are capable of wide-ranging movements.

Florida manatees are generally restricted to peninsular Florida due to their inability to thermoregulate and their need for warm water to survive the winter (FWC, 2007). Specifically, during the months of December through February, manatees seek shelter from the cold at a limited number of warm-water sites or areas in the southern two-thirds of Florida (FWC, 2007). These aggregation sites include eight principal power plant thermal outfalls (five on the Atlantic coast, three on the Gulf coast) and four major artesian springs (Blue Spring, Crystal River, Homosassa Springs, and Warm Mineral Springs) that are frequented by a large proportion of the manatees counted during synoptic surveys (FWC, 2007). Some winter aggregations can number in the hundreds. Other industrial outfalls, smaller springs, and passive thermal basins that retain heat longer than ambient waters provide additional secondary warm-water habitat for manatees (FWC, 2007). From March through November, manatees disperse throughout the coastal waters, estuaries, and major rivers of Florida. Some migrate to neighboring states, particularly southeastern Georgia and there are reports of some individuals traveling as far north as Massachusetts and west to Texas (FWC, 2007). Additional information on reproductive areas and seasons is not available for this species.

Diving Behavior – Manatees are shallow divers. The distribution of preferred seagrasses is mostly limited to high-light areas; therefore, manatees are fairly restricted to shallower near-shore waters (Wells et al., 1999). It is unlikely that manatees descend much deeper than 20 m (66 ft), and don't usually remain submerged for longer than 2 to 3 minutes. However, when bottom resting, manatees have been known to stay submerged for up to 24 minutes (Wells et al., 1999).

Acoustics and Hearing – West Indian manatees produce a variety of squeak-like sounds that have a typical frequency range of 0.6 to 12 kHz (dominant frequency range from 2 to 5 kHz), and last 0.18 to 0.9 sec. Recently, vocalizations below 0.1 kHz have also been recorded. Overall, manatee vocalizations are considered relatively stereotypic, with little variation between isolated populations examined. However, vocalizations have been newly shown to possess nonlinear dynamic characteristics (e.g., subharmonics or abrupt, unpredictable transitions between frequencies) aid in individual recognition and mother-calf communication. Average source levels for vocalizations have been calculated to range from 90 to 138 dB re 1 μPa (average: 100 to 112 dB re 1 μPa).

Audiogram work suggests that manatees may hear better than originally suggested. Manatees have high-frequency sensitivity, narrow critical bands, and pulsed broadband calls. Behavioral data on two animals indicate an underwater hearing range of approximately 0.4 to 46 kHz, with best sensitivity between 16 and 18 kHz (50 dB re 1 μPa-m), while earlier electrophysiological studies indicated best sensitivity from 1 to 1.5 kHz.

Occurrence in NSWC PCD Study Area – During warmer months, manatees are common along the Gulf Coast of Florida from the Everglades National Park northward to the Suwannee River in northwestern Florida, and are less common farther westward. In winter, the GOM subpopulations move southward to warmer waters. The winter range is restricted to waters at the southern tip of Florida and to waters near localized warm-water sources, such as power plant outfalls and natural springs in west-central Florida. Crystal River in Citrus County is typically the northern limit of the manatee's winter range on the Gulf Coast. Manatees are uncommon west of the Suwannee River in Florida and are infrequently found as far west as Texas. The Florida Gulf Coast population of manatees is estimated to be approximately 1,520 individuals (Minerals Management Service, 2006). The manatee occurs in nearshore waters to the east of the NSWC PCD Study Area, and the probability of encountering manatees in the NSWC PCD Study Area is highly unlikely.

4.4 SUMMARY OF SPECIES INCLUDED IN THIS ANALYSIS

Table 4-1 identifies the species included in the analysis and provides a basis for the species that are eliminated from further discussion in this LOA.

Table 4-1. Marine Mammals in the GOM

Species	Included in analysis	Reason for dismissal
North Atlantic right whale *Eubalaena glacialis*		Right whales are considered extralimital to the NSWC PCD Study Area. The species is dismissed from further discussion and analysis.
Humpback whale *Megaptera novaeangliae*		Humpback whales are considered extralimital to the NSWC PCD Study Area; therefore, the species is dismissed from further examination.
Sei whale *Balaenoptera borealis*		Sei whales are considered extralimital to the NSWC PCD Study Area. Thus, the species is dismissed from further discussion and analysis.
Fin whale *Balaenoptera physalus*		Fin whales are considered extralimital to the NSWC PCD Study Area. They are dismissed from further examination.
Blue whale *Balaenoptera musculus*		Blue whales are considered extralimital to the NSWC PCD Study Area; therefore, the species is dismissed from further discussion and analysis.
Bryde's whale *Balaenoptera edeni*	X	
Sperm whale *Physeter macrocephalus*	X	
Minke whale *Balaenoptera acutorostrata*		Low occurrence in the GOM, with no distribution expected in the NSWC PCD Study Area. Thus, the species is dismissed from further discussion and analysis.
Pygmy sperm whale *Kogia breviceps*	X	
Dwarf sperm whale *Kogia simus*	X	
Cuvier's beaked whale *Ziphius cavirostris*	X	
Gervais' beaked whale *Mesoplodon europaeus*	X	
Sowerby's beaked whale *Mesoplodon bidens*	X	
True's beaked whale *Mesoplodon mirus*	X	
Blainville's beaked whale *Mesoplodon densirostris*	X	
Killer whale *Orcinus orca*	X	
False killer whale *Pseudorca crassidens*	X	

Table 4-1. Marine Mammals in the GOM Cont'd

Species	Included in analysis	Reason for dismissal
Pygmy killer whale *Feresa attenuata*	X	
Short-finned pilot whale *Globicephala macrorhynchus*		The species is considered extralimital to the NSWC PCD Study Area and is dismissed from further examination.
Risso's dolphin *Grampus griseus*	X	
Melon-headed whale *Peponocephala electra*		The melon-headed whale is not expected in the NSWC PCD Study Area. Therefore, it is dismissed from further analysis and discussion.
Rough-toothed dolphin *Steno bredanensis*	X	
Atlantic bottlenose dolphin *Tursiops truncatus*	X	
Atlantic spotted dolphin *Stenella frontalis*	X	
Pantropical spotted dolphin *Stenella attenuata*	X	
Striped dolphin *Stenella coeruleoalba*	X	
Spinner dolphin *Stenella longirostris*	X	
Clymene dolphin *Stenella clymene*	X	
Fraser's dolphin *Lagenodelphis hosei*	X	
West Indian manatee *Trichechus manatus*		Manatees are considered rare in the NSWC PCD Study Area. Thus, they are dismissed from further analysis.

Source: DON, 2007
[a] FE = Federal endangered

4.5 CETACEAN STRANDING EVENTS

When a live or dead marine mammal swims or floats onto shore and becomes "beached" or incapable of returning to sea, the event is termed a "stranding" (Perrin and Geraci, 2002; Geraci and Lounsbury, 2005; NMFS, 2007). The legal definition for a stranding within the United States is that "a marine mammal is dead and is (i) on a beach or shore of the United States; or (ii) in waters under the jurisdiction of the United States (including any navigable waters); or (B) a marine mammal is alive and is (i) on a beach or shore of the United States and is unable to return to the water; (ii) on a beach or shore of the United States and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the

United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance” (16 U.S.C. 1421h).

The majority of animals that strand are dead or moribund (i.e., dying) (NMFS, 2007). For animals that strand alive, human intervention through medical aid and/or guidance seaward may be required for the animal to return to the sea. If unable to return to sea, rehabilitation at an appropriate facility may be determined as the best opportunity for animal survival. An event where animals are found out of their normal habitat is may be considered a stranding depending on circumstances even though animals do not necessarily end up beaching (Southhall, 2006).

Three general categories can be used to describe strandings: single, mass, and unusual mortality events. The most frequent type of stranding is a single stranding, which involves only one animal (or a mother/calf pair) (NMFS, 2007).

Mass stranding involves two or more marine mammals of the same species other than a mother/calf pair (Wilkinson, 1991), and may span one or more days and range over several miles (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Walsh et al., 2001; Freitas, 2004). In North America, only a few species typically strand in large groups of 15 or more and include sperm whales, pilot whales, false killer whales, Atlantic white-sided dolphins, white-beaked dolphins, and rough-toothed dolphins (Odell 1987; Walsh et al., 2001). Some species, such as pilot whales, false-killer whales, and melon-headed whales occasionally strand in groups of 50 to 150 or more (Geraci et al. 1999). All of these normally pelagic off-shore species are highly sociable and usually infrequently encountered in coastal waters. Species that commonly strand in smaller numbers include pygmy killer whales, common dolphins, bottlenose dolphins, Pacific white--sided dolphin Frasier’s dolphins, gray whale and humpback whale (West Coast only), harbor porpoise, Cuvier’s beaked whales, California sea lions, and harbor seals (Mazzuca et al. 1999, Norman et al., 2004, Geraci and Lounsbury 2005).

Unusual mortality events (UMEs) can be a series of single strandings or mass strandings, or unexpected mortalities (i.e., die-offs) that occur under unusual circumstances (Dierauf and Gulland, 2001; Harwood, 2002; Gulland, 2006; NMFS, 2007). These events may be interrelated: for instance, at-sea die-offs lead to increased stranding frequency over a short period of time, generally within one to two months. As published by NMFS, revised criteria for defining a UME include the following (Hohn et al., 2006):

1. A marked increase in the magnitude or a marked change in the nature of morbidity, mortality, or strandings when compared with prior records.
2. A temporal change in morbidity, mortality, or strandings is occurring.
3. A spatial change in morbidity, mortality, or strandings is occurring.
4. The species, age, or sex composition of the affected animals is different than that of animals that are normally affected.
5. Affected animals exhibit similar or unusual pathologic findings, behavior patterns, clinical signs, or general physical condition (e.g., blubber thickness).
6. Potentially significant morbidity, mortality, or stranding is observed in species, stocks or populations that are particularly vulnerable (e.g., listed as depleted, threatened or

endangered or declining). For example, stranding of three or four right whales may be cause for great concern whereas stranding of a similar number of fin whales may not.

7. Morbidity is observed concurrent with or as part of an unexplained continual decline of a marine mammal population, stock, or species.

UMEs are usually unexpected, infrequent, and may involve a significant number of marine mammal mortalities. As discussed below, unusual environmental conditions are probably responsible for most UMEs and marine mammal die-offs (Vidal and Gallo-Reynoso, 1996; Geraci et al., 1999; Walsh et al., 2001; Gulland and Hall, 2005).

Reports of marine mammal strandings can be traced back to ancient Greece (Walsh et al., 2001). Like any wildlife population, there are normal background mortality rates that influence marine mammal population dynamics, including starvation, predation, aging, reproductive success, and disease (Geraci et al., 1999; Carretta et al., 2007). Strandings in and of themselves may be reflective of this natural cycle or, more recently, may be the result of anthropogenic sources (i.e., human impacts). Current science suggests that multiple factors, both natural and man-made, may be acting alone or in combination to cause a marine mammal to strand (Geraci et al., 1999; Culik, 2002; Perrin and Geraci, 2002; Hoelzel, 2003; Geraci and Lounsbury, 2005; NRC, 2006). While post-stranding data collection and necropsies of dead animals are attempted in an effort to find a possible cause for the stranding, it is often difficult to pinpoint exactly one factor that can be blamed for any given stranding. An animal suffering from one ailment becomes susceptible to various other influences because of its weakened condition, making it difficult to determine a primary cause. In many stranding cases, scientists never learn the exact reason for the stranding. Specific potential stranding causes can include both natural and human influenced (anthropogenic) causes as listed below:

Natural Stranding Causes

- Disease
- Natural toxins
- Weather and climatic influences
- Navigation errors
- Social cohesion
- Predation

Human Influenced (Anthropogenic) Stranding Causes

- Fisheries interaction
- Vessel strike
- Pollution and ingestion
- Noise

Specific beaked whale stranding events associated with potential naval operations are as follows:

- May 1996: Greece (North Atlantic Treaty Organization [NATO]/U.S.)

- March 2000: Bahamas (U.S.)
- May 2000: Portugal, Madeira Islands (NATO/U.S.)
- September 2002: Canary Islands (NATO/U.S.)
- January 2006: Spain, Mediterranean Sea coast (NATO/U.S.)

These events represent a small overall number of animals (40 animals) over an 11 year period and not all worldwide beaked whale strandings can be linked to naval activity (International Council for Exploration of the Sea [ICES], 2005a; 2005b; Podesta et al., 2006). Four (Greece, Portugal, Spain) of the five events occurred during NATO exercises or events where DON presence was limited. One (Bahamas) of the five events involved only DON ships. These five events are described briefly below. For detailed information on these events, refer to Appendix D, Cetacean Stranding Report.

- May 1996 Greece - Twelve Cuvier's beaked whales (*Ziphius cavirostris*) stranded along the coast of the Kyparissiakos Gulf on May 12 and 13, 1996 (Frantzis, 1998). From May 11 through May 15, the NATO research vessel Alliance was conducting sonar tests with signals of 600 Hz and 3 kHz and root-mean-squared (rms) sound pressure levels (SPL) of 228 and 226 dB re: 1μPa, respectively (D'Amico and Verboom, 1998; D'Spain et al., 2006). The timing and the location of the testing encompassed the time and location of the whale strandings (Frantzis, 1998). However, because information for the necropsies was incomplete and inconclusive, the cause of the stranding cannot be precisely determined.
- March 2000, Bahamas – Seventeen marine mammals comprised of Cuvier's beaked whales, Blainville's beaked whales (*Mesoplodon densirostris*), minke whale (*Balaenoptera acutorostrata*), and one spotted dolphin (*Stenella frontalis*), stranded along the Northeast and Northwest Providence Channels of the Bahamas Islands on March 15-–16, 2000 (Evans and England, 2001). The strandings occurred over a 36- hour period and coincided with DON use of mid-frequency active sonar within the channel. Navy ships were involved in tactical sonar exercises for approximately 16 hours on March 15. The ships, which operated the AN/SQS-53C and AN/SQS-56, moved through the channel while emitting sonar pings approximately every 24 seconds. The timing of pings was staggered between ships and average source levels of pings varied from a nominal 235 dB SPL (AN/SQS-53C) to 223 dB SPL (AN/SQS-56). The center frequency of pings was 3.3 kHz and 6.8 to 8.2 kHz, respectively. Passive acoustic monitoring records demonstrated that no large scale acoustic activity besides the Navy sonar exercise occurred in the times surrounding the stranding event. The mechanism by which sonar could have caused the observed traumas or caused the animals to strand was undetermined.
- May 2000, Madeira Island, Portugal – Three Cuvier's beaked whales stranded on two islands in the Madeira Archipelago, Portugal, from May 10 – 14, 2000 (Cox et al., 2006). A joint NATO amphibious training exercise, named "Linked Seas 2000," which involved participants from 17 countries, took place in Portugal during May 2 – 15, 2000. The timing and location of the exercises overlapped with that of the stranding incident. Although the details about whether or how sonar was used during "Linked Seas 2000" is

unknown, the presence of naval activity within the region at the time of the strandings suggested a possible relationship to Navy activity.

- September 2002, Canary Islands – On September 24, 2002, 14 beaked whales stranded on Fuerteventura and Lanzaote Islands in the Canary Islands (Jepson et al., 2003). At the time of the strandings, an international naval exercise called (Neo-Tapon, 2002) that involved numerous surface warships and several submarines was being conducted off the coast of the Canary Islands. Tactical mid-frequency active sonar was utilized during the exercises, and strandings began within hours of the onset of the use of mid-frequency sonar (Fernández et al., 2005). The association of NATO mid-frequency sonar use close in space and time to the beaked whale strandings, and the similarity between this stranding event and previous beaked whale mass strandings coincident with sonar use, suggests that a similar scenario and causative mechanism of stranding may be shared between the events.
- January 2006, Spain – The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26 to –28, 2006, on the southeast coast of
- Spain near Mojacar (Gulf of Vera) in the Western Mediterranean Sea. From January 25--26, 2006, a NATO surface ship group (seven ships including one U.S. ship under NATO operational command) conducted active sonar training against a Spanish submarine within 50 NM of the stranding site. According to the pathologists, a likely cause of this type of beaked whale mass stranding event may have been anthropogenic acoustic activities. However, no detailed pathological results confirming this supposition have been published to date, and no positive acoustic link was established as a direct cause of the stranding.

By comparison, potential impacts to all species of cetaceans worldwide from fishery related mortality can be orders of magnitude more significant (100,000s of animals versus 10s of animals) (Culik, 2002; ICES, 2005b; Read et al., 2006). This does not negate the influence of any mortality or additional stressor to small, regionalized sub-populations which may be at greater risk from human related mortalities (fishing, vessel strike, sound) than populations with larger oceanic level distribution or migrations. ICES (2005a) noted, however, that taken in context of marine mammal populations in general, sonar is not a major threat, or significant portion of the overall ocean noise budget. A constructive framework and continued research based on sound scientific principles is needed in order to avoid speculation as to stranding causes, and to further our understanding of potential effects or lack of effects from military mid-frequency sonar (Bradshaw et al., 2006; ICES 2005b; Barlow and Gisiner, 2006; Cox et al., 2006).

Refer to Appendix D, Marine Mammal Stranding Report, for additional information on the history of stranding, a description of the above-listed stranding events, a review of the many different possible reasons for stranding, as well as the stranding investigation findings and conclusions.

This page is intentionally blank.

5. HARASSMENT AUTHORIZATION REQUESTED

The United States (U.S.) Navy requests a Letter of Authorization (LOA) for the incidental harassment of marine mammals pursuant to Section 101(a)(5)(D) of the Marine Mammal Protection Act (MMPA), valid for a five year period commencing July 2009. The Navy's request includes authorization for:

- Level A harassment by ordnance activities,
- Level B harassment from TTS by sonar and ordnance activities, and
- Level B harassment from behavior by sonar, ordnance, and projectile firing activities.

It is understood that an LOA is applicable to activities that may result in incidental take (Level A or Level B harassment) of marine mammal species. Section 6.0 provides details on the species and numbers of takes requested.

This page is intentionally blank.

6. NUMBERS AND SPECIES EXPOSED

The Marine Mammal Protection Act (MMPA) requires applicants to determine the number of marine mammals that are expected to be incidentally harassed by an action and the nature of the harassment (Level A or Level B). The Proposed Action is a military readiness activity as defined in the MMPA, and the sections below define MMPA Level A and Level B as applicable to military readiness activities. The following sections discuss the potential for ship strikes to occur from surface operations, potential effects from noise related to sonar, potential effects from noise related to ordnance, potential effects from noise related to projectile firing operations, and direct physical impacts from projectile firing,. Section 6.2.1 presents how the Level A and Level B harassment definitions were applied to develop the quantitative acoustic analysis methodologies used to assess the potential for the Proposed Action to affect marine mammals.

6.1 SURFACE OPERATIONS

6.1.1 Introduction and Approach to Analysis

Typical operations occurring at the surface includes the deployment or towing of Mine Countermeasures (MCM) equipment, retrieval of equipment, and clearing and monitoring for non-participating vessels. As such, the potential exists for a ship to strike a marine mammal while conducting Surface Operations. In an effort to reduce the likelihood of a ship strike, the protective measures mentioned in Chapter 11 will be implemented.

6.1.2 Territorial Waters

Collisions with commercial and U.S. Navy ships can cause major wounds and may occasionally cause fatalities to marine mammals. The most vulnerable marine mammals are those that spend extended periods of time at the surface in order to restore oxygen levels within their tissues after deep dives (e.g., the sperm whale). Laist et al. (2001) identified 11 species known to be hit by ships worldwide. Of these species, fin whales are struck most frequently; right whales, humpback whales, sperm whales, and gray whales are hit commonly. More specifically, from 1975 through 1996, there were 31 dead whale strandings involving four large whales along the GOM coastline. Stranded animals included two sei whales, four minke whales, eight Bryde's whales, and 17 sperm whales. Only one of the stranded animals, a sperm whale with propeller wounds found in Louisiana on 9 March 1990, was identified as a result of a possible ship strike (Laist et al., 2001). In addition, from 1999 through 2003, there was only one stranding involving a false killer whale in the northern GOM (Alabama 1999) (Waring et al., 2006). None of these identified species are likely to occur in the territorial waters of the Naval Surface Warfare Center Panama City division (NSWC PCD) Study Area. This area encompasses waters that are less than 33 m (108 ft) in depth and it is unlikely any species including Bryde's whales are located here.

In addition, manatee mortality statistics from 1986 through 2005 list four watercraft-related manatee deaths in Taylor and Wakulla Counties. The May 1997 death in Taylor County occurred in the Steinhatchee River; the June 2000 death in Wakulla County occurred in St. Marks River; the April 2002 death in Taylor County occurred in the GOM; and the June 2004 death in

Wakulla County occurred in the Wakulla River (FWC, 2007b). Details regarding the circumstances or the type of ship (i.e., naval, commercial, recreational, etc.) involved in these four strikes are not available. The NSWC PCD Study Area does not include Taylor or Wakulla County. Although manatees have been sporadically sighted in the NSWC PCD Study Area, their occurrence is unlikely because this area is to the north and west of their range and outside of conditions for their optimal habitat. Therefore, there will be no effect to manatees from ship strikes.

It is unlikely that activities in territorial waters will result in a ship strike because of the nature of the operations and size of the vessels. For example, the hours of surface operations take into consideration operation times for multiple vessels during each test event. These vessels range in size from small rigid hull inflatable boat (RHIB) to surface vessels of approximately 180 feet. The majority of these vessels are small RHIBs and medium-sized vessels. A large proportion of the timeframe for NSWC PCD test events include periods when ships remain stationary within the test site. The greatest time spent in transit for tests includes navigation to and from the sites. At these times, the Navy follows standard operating procedures (SOPs). The captain and other crew members keep watch during ship transits to avoid objects in the water. Furthermore, the proposed protective measures described in Chapter 5 will ensure that no ship strikes will occur. The Navy concludes that ship strikes will not affect annual rates of recruitment or survival and will not result in any takes of marine mammals in territorial waters.

Based on the analysis provided above, the likelihood that a ship will strike a marine mammal is low. The proposed protective measures listed in Chapter 11 will be implemented to reduce the likelihood even further for a ship strike to occur. The Navy finds that there will be no take of marine mammals from surface operations in non-territorial waters and that ship strikes will not affect annual rates of recruitment or survival.

6.1.3 Non-territorial Waters

As stated in Section 6.1.2, there are six reports of possible watercraft related marine mammal deaths in the GOM. These deaths include one sperm whale found with propeller wounds in Louisiana in March 1990; one false killer whale in Alabama in 1999; and four manatees in Taylor and Wakulla Counties, Florida, from May 1997 through June 2004 (Laist et al., 2001; Waring et al., 2007; and FWC, 2007b). Of these six deaths, only two are applicable to non-territorial waters since manatees are not expected to venture outside shallow coastal waters. According to the 2005 Stock Assessment Report, no other marine mammal that is likely to occur in the northern GOM has been reported as either seriously or fatally injured from 1999 through 2003 (Waring et al., 2007). Thus, the potential effects to marine mammals in non-territorial waters will be similar to those described in territorial waters.

It is unlikely that activities in territorial waters will result in a ship strike because of the nature of the operations and size of the vessels. For example, the hours of surface operations take into consideration operation times for multiple vessels during each test event. These vessels range in size from small RHIB to surface vessels of approximately 180 feet. The majority of these vessels are small RHIBs and medium-sized vessels. A large proportion of the timeframe for NSWC PCD test events include periods when ships remain stationary within the test site. The greatest time spent in transit for tests includes navigation to and from the sites. At these times, the Navy follows SOPs. The captain and other crew members keep watch during ship transits to avoid objects in the water. In addition, the proposed protective measures and Navy SOPs and protective measures listed in Chapter 5 will ensure that no ship strikes occur to marine mammals in non-territorial waters.

6.2 ACOUSTIC EFFECTS: SONAR

6.2.1 Introduction and Approach to Analysis

NSWC PCD RDT&E activities include sonar operations in the mid- and high- frequency ranges. The majority of operating hours for systems encompass high frequencies; less than 10 percent of the test hours involve mid-frequency systems while over 90 percent of all NSWC PCD RDT&E sonar activities encompass high- frequency sonar sources. The test events differ significantly from major Navy exercises and training. Sonar sources are deployed for short periods of time by NSWC PCD personnel and its customers to evaluate systems while major Navy training involves the use of sonar over long periods of time. Unlike the training environment where the Navy deploys multiple sonar systems with numerous sources and operates many systems at once from multiple platforms, testing at the NSWC PCD involves only one system and a limited number of acoustic sources activitated at once. The following subsections present the background information for evaluation of potential exposures marine mammals from active sonar at the NSWC PCD.

MMPA Level A and Level B Harassment

Categorizing potential effects as either physiological or behavioral effects allows them to be related to the harassment definitions. For military readiness activities, Level A harassment includes any act that injures or has the significant potential to injure a marine mammal or marine mammal stock in the wild. Injury is the destruction or loss of biological tissue (DON, 2006; DON, 2006a; NOAA, 2006). The destruction or loss of biological tissue will result in an alteration of physiological function that exceeds the normal daily physiological variation of the intact tissue. For example, increased localized histamine production, edema, production of scar tissue, activation of clotting factors, white blood cell response, etc., may be expected following injury. Therefore, the NSWC PCD Letter of Authorization (LOA) assumes that all injury is qualified as a physiological effect and, to be consistent with prior actions and policy (DON, 2006; DON, 2006a; NOAA, 2006), all injuries (slight to severe) are considered Level A harassment.

Public Law (PL) 108-136 (2004) amended the definition of Level B harassment under the MMPA for military readiness activities, such as this action (and also for scientific research on marine mammals conducted by or on the behalf of the federal government). For military readiness activities, Level B harassment is now 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.” Unlike Level A harassment, which is solely associated with physiological effects, both physiological and behavioral effects may cause Level B harassment.

The amended definition of Level B harassment serves to clarify and codify National Marine Fisheries Service (NMFS's) existing interpretation of Level B harassment. The intent of the unique definition of harassment for military readiness activities and specific scientific activities was to provide greater clarity for DoD and the regulatory agencies. In addition the definition now takes a more science-based approach by properly focusing on activities that result in significant behavioral changes in biologically important activities, rather than activities with *de minimus* effects. Replacement of the threshold standard "potential" with "likely" eliminates from consideration those activities that have a mere "potential" to have effects. Unlike Level A harassment, which is solely associated with physiological effects, both physiological and behavioral effects may cause Level B harassment.

Some physiological effects can occur that are non-injurious but that can potentially disrupt the behavior of a marine mammal. These include temporary distortions in sensory tissue that alter physiological function but that are fully recoverable without the requirement for tissue replacement or regeneration. For example, an animal that experiences a temporary reduction in hearing sensitivity suffers no injury to its auditory system but may not perceive some sounds due to the reduction in sensitivity. As a result, the animal may not respond to sounds that would normally produce a behavioral reaction. This lack of response qualifies as a temporary disruption of normal behavioral patterns; the animal is impeded from responding in a normal manner to an acoustic stimulus. The analysis presented in this document assumes all temporary hearing impairment (slight to severe) is considered Level B harassment, even if the effect from the temporary impairment is biologically insignificant.

The harassment status of slight behavioral disruption (without physiological effects) has been addressed in previous actions and policies (DON, 2006). The conclusion is that a certain momentary behavioral reaction of an animal to a brief, time-isolated acoustic event does not qualify as Level B harassment. A more general conclusion, that Level B harassment occurs only when there is "a potential for a significant behavioral change or response in a biologically important behavior or activity," is found in recent actions and policies (DON, 2006).

Although the temporary lack of response discussed above may not result in abandonment or significant alteration of natural behavioral patterns, to be conservative, the inputs to the acoustic model were based on the assumption that temporary hearing impairment (slight to severe) would result in Level B harassment. The above conclusions and definitions of harassment, including the 2004 amendments to the definitions of harassment, were considered in the context of the proposed NSWC PCD activities in developing conservative thresholds for behavioral disruptions. As a result, the actual incidental harassment of marine mammals associated with this action may be less than that calculated.

MMPA Exposure Zones

Two acoustic modeling approaches were used to account for both physiological and behavioral effects to marine mammals. This subsection on exposure zones is specific to the modeling of total energy. When using a threshold of accumulated energy, the volumes of ocean in which Level A and Level B harassment were predicted to occur are called "exposure zones." As a conservative estimate, all marine mammals predicted to be in an exposure zone were considered exposed over time to accumulated sound levels that may result in harassment within the applicable Level A or Level B harassment categories. Figure 6-1 illustrates exposure zones extending from a hypothetical, directional sound source.

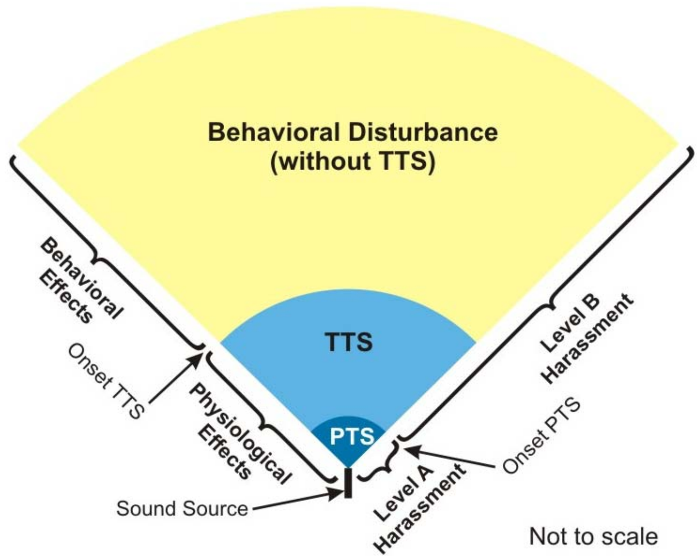


Figure 6-1. Illustration of the Acoustic Effect Framework Used in this LOA

The Level A exposure zone extends from the source out to the distance and exposure at which the slightest amount of injury is predicted to occur. The acoustic exposure that produces the slightest degree of injury is therefore the threshold value defining the outermost limit of the Level A exposure zone. Use of the threshold associated with the onset of slight injury as the most distant point and least-injurious exposure takes into account all more serious injuries within the Level A exposure zone.

The Level B exposure zone begins just outside the point of slightest injury and extends outward from that point to include all animals that may possibly experience Level B harassment. Physiological effects extend beyond the range of slightest injury to a point where slight temporary distortion of the most sensitive tissue occurs, but without destruction or loss of that tissue. The animals predicted to be in this zone are assumed to experience Level B harassment by virtue of temporary impairment of sensory function (altered physiological function) that can disrupt behavior.

Auditory Tissues as Indicators of Physiological Effects

Exposure to continuous-type sound may cause a variety of physiological effects in mammals. For example, exposure to very high sound levels may affect the function of the visual system, vestibular system, and internal organs (Ward, 1997). Exposure to high-intensity, continuous-type sounds of sufficient duration may cause injury to the lungs and intestines (e.g., Dalecki et al., 2002). Sudden, intense sounds may elicit a "startle" response and may be followed by an orienting reflex (Ward, 1997; Jansen, 1998). The primary physiological effects of sound, however, are on the auditory system (Ward, 1997).

The mammalian auditory system consists of the outer ear, middle ear, inner ear, and central nervous system. Sound waves are transmitted through the middle ears to fluids within the inner ear, except in cetaceans. The inner ear contains delicate electromechanical hair cells that convert the fluid motions into neural impulses that are sent to the brain. The hair cells within the inner ear are the most vulnerable to overstimulation by sound exposure (Yost, 1994).

Very high sound levels may rupture the eardrum or damage the small bones in the middle ear (Yost, 1994). Lower level exposures of sufficient duration may cause permanent or temporary hearing loss; such an effect is called a sound-induced threshold shift, or simply a threshold shift (TS) (Miller, 1974). A TS may be either temporary (TTS) or permanent (PTS). PTS does not equal permanent hearing loss; it is more correctly described as a permanent loss of hearing sensitivity, usually over a subset of the animal's hearing range. Similarly, TTS is a temporary hearing sensitivity loss, usually over a subset of the animal's hearing range. Still lower levels of sound may result in auditory masking, which may interfere with an animal's ability to hear other concurrent sounds.

Because the tissues of the ear appear to be the most susceptible to the physiological effects of sound and TSs tend to occur at lower exposures than other more serious auditory effects, PTS and TTS are used here as the biological indicators of physiological effects. TTS is the first indication of physiological noninjurious change and is not physical injury. The remainder of this section is, therefore, focused on TSs, including PTSs and TTSs. Since masking (without a resulting TS) is not associated with abnormal physiological function, it is not considered a physiological effect for this assessment but rather a potential behavioral effect.

Sound-Induced Threshold Shifts

The amount of TS depends on the amplitude, duration, frequency, and temporal pattern of the sound exposure. Threshold shifts generally increase with the amplitude and duration of sound exposure. For continuous sounds, exposures of equal energy lead to approximately equal effects (Ward, 1997). For intermittent sounds, less TS occurs than from a continuous exposure with the same energy (some recovery will occur between exposures) (Kryter et al., 1966; Ward, 1997).

The magnitude of a TS normally decreases with the amount of time post-exposure (Miller, 1974). The amount of TS just after exposure is called the initial TS. If the TS activity returns to zero (the threshold returns to the pre-exposure value), the TS is a TTS. Since the amount of TTS depends on the time post-exposure, it is common to use a subscript to indicate the time in minutes after exposure (Quaranta et al., 1998). For example, TTS_2 means a TTS measured two minutes after exposure. If the TS does not return to zero but leaves some finite amount of TS, then that remaining TS is a PTS. The distinction between PTS and TTS is based on whether there is a complete recovery of a TS following a sound exposure. Figure 6-2 shows two hypothetical TSs: one that completely recovers (a TTS) and one that does not completely recover, leaving some PTS.

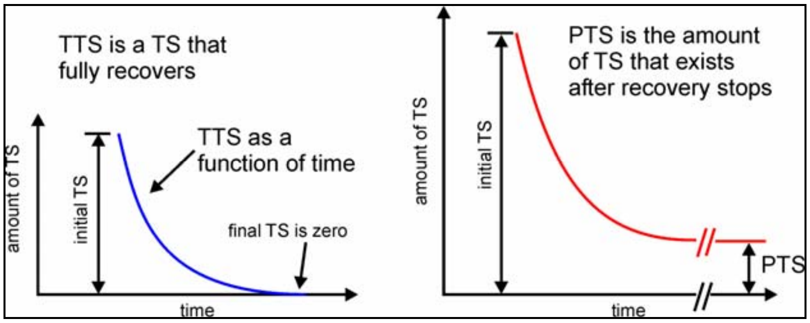


Figure 6-2. Hypothetical Temporary and Permanent Threshold Shifts

PTS, TTS and Exposure Zones

PTS is nonrecoverable and therefore qualifies as an injury and is classified as Level A harassment under the wording of the MMPA. The smallest amount of PTS (onset-PTS) is taken to be the indicator for the smallest degree of injury that can be measured. The acoustic exposure associated with onset-PTS is used to define the outer limit of the Level A exposure zone.

TTS is recoverable and, as in recent rulings (NOAA, 2001; 2002a), is considered to result from the temporary, noninjurious distortion of hearing-related tissues. In the NSWC PCD Study Area, the smallest measurable amount of TTS (onset-TTS) is taken as the best indicator for slight temporary sensory impairment. Because it is considered noninjurious, the acoustic exposure associated with onset-TTS is used to define the outer limit of the portion of the Level B exposure zone attributable to physiological effects. This follows from the concept that hearing loss potentially affects an animal's ability to react normally to the sounds around it. Therefore, in this LOA, the potential for TTS is considered as a Level B harassment that is mediated by physiological effects upon the auditory system.

Criteria and Thresholds for Physiological Effects

This section presents the effect criteria and thresholds for physiological effects of sound leading to injury and behavioral disturbance as a result of sensory impairment. The tissues of the ear are the most susceptible to physiological effects of underwater sound. PTS and TTS were determined to be the most appropriate biological indicators of physiological effects that equate to the onset of injury (Level A harassment) and behavioral disturbance (Level B harassment), respectively. This section is, therefore, focused on criteria and thresholds to predict PTS and TTS in marine mammals.

The most appropriate information from which to develop PTS/TTS criteria for marine mammals is experimental measurements of PTS and TTS from marine mammal species of interest. TTS data exist for several marine mammal species and may be used to develop meaningful TTS criteria and thresholds. PTS data do not exist for marine mammals and are unlikely to be obtained. Therefore, PTS criteria must be developed from TTS criteria and estimates of the relationship between TTS and PTS.

This section begins with a review of the existing marine mammal TTS data. The review is followed by a discussion of the relationship between TTS and PTS. The specific criteria and thresholds for TTS and PTS used in this LOA are then presented. This is followed by discussions of sound energy flux density level (EL), the relationship between EL and sound pressure level (SPL), and the use of SPL and EL in previous environmental compliance documents.

Energy Flux Density Level and Sound Pressure Level

EL is a measure of the sound energy flow per unit area expressed in dB. EL is stated in dB re 1 μPa^2-s for underwater sound and dB re 20 μPa^2-s for airborne sound.

SPL is a measure of the root mean square, or "effective," sound pressure in decibels. SPL is expressed in dB re 1 µPa for underwater sound and dB re 20 µPa for airborne sound.

TTS in Marine Mammals

A number of investigators have measured TTS in marine mammals. These studies measured hearing thresholds in trained marine mammals before and after exposure to intense sounds. Some of the more important data obtained from these studies are onset TTS levels, exposure levels sufficient to cause a just-measurable amount of TTS, often defined as 6 dB of TTS (e.g., Schlundt et al., 2000). The existing marine mammal TTS data are summarized in the following paragraphs.

Schlundt et al. (2000) reported the results of TTS experiments conducted with bottlenose dolphins and beluga whales exposed to one second tones. This paper also includes a re-analysis of preliminary TTS data released in a technical report by Ridgway et al. (1997). At frequencies of 3, 10, and 20 kilohertz (kHz), SPLs necessary to induce measurable amounts (6 dB or more) of TTS were between 192 and 201 dB re 1 µPa (EL = 192 to 201 dB re 1 μPa^2-s). The mean exposure SPL and EL for onset-TTS were 195 dB re 1 µPa and 195 dB re 1 μPa^2-s, respectively. The sound exposure stimuli (tones) and relatively large number of test subjects (five dolphins and two beluga whales) make the Schlundt et al. (2000) data the most directly relevant TTS information for the scenarios described in this LOA.

Finneran et al. (2001, 2003, 2005) described TTS experiments conducted with bottlenose dolphins exposed to 3 kHz tones with durations of 1, 2, 4, and 8 seconds. Small amounts of TTS (3 to 6 dB) were observed in one dolphin after exposure to ELs between 190 and 204 dB re 1 μPa^2-s. These results were consistent with the data of Schlundt et al. (2000) and showed that the Schlundt et al. (2000) data were not significantly affected by the masking sound used. These results also confirmed that, for tones with different durations, the amount of TTS is best correlated with the exposure EL rather than the exposure SPL.

Nachtigall et al. (2003a, 2004) measured TTS in a bottlenose dolphin exposed to octave-band sound centered at 7.5 kHz. Nachtigall et al. (2003a) reported TTSs of about 11 dB measured 10 to 15 minutes after exposure to 30 to 50 minutes of sound with SPL 179 dB re 1 µPa (EL about 213 dB re μPa^2-s). No TTS was observed after exposure to the same sound at 165 and 171 dB re 1 µPa. Nachtigall et al. (2004) reported TTSs of around 4 to 8 dB 5 minutes after exposure to 30 to 50 minutes of sound with SPL 160 dB re 1 µPa (EL about 193 to 195 dB re 1 µPa^2-s). The difference in results was attributed to faster post-exposure threshold measurement; TTS may have recovered before being detected by Nachtigall et al. (2003a). These studies showed that, for long-duration exposures, lower sound pressures are required to induce TTS than are required for short-duration tones. These data also confirmed that, for the cetaceans studied, EL is the most appropriate predictor for onset-TTS.

Finneran et al. (2000, 2002) conducted TTS experiments with dolphins and beluga whales exposed to impulsive sounds similar to those produced by distant underwater explosions and seismic waterguns. These studies showed that, for very short-duration impulsive sounds, higher sound pressures were required to induce TTS than for longer-duration tones.

Kastak et al. (1999, 2005) conducted TTS experiments with three species of pinnipeds, California sea lion, northern elephant seal, and a Pacific harbor seal exposed to continuous underwater sounds at levels of 80 and 95 dB Sensation Level (SL) at 2.5 and 3.5 kHz for up to 50 minutes. Mean TTS shifts of up to 12.2 dB occurred with the harbor seals showing the largest shift of 28.1 dB. Increasing the sound duration had a greater effect on TTS than increasing the sound level from 80 to 95 dB.

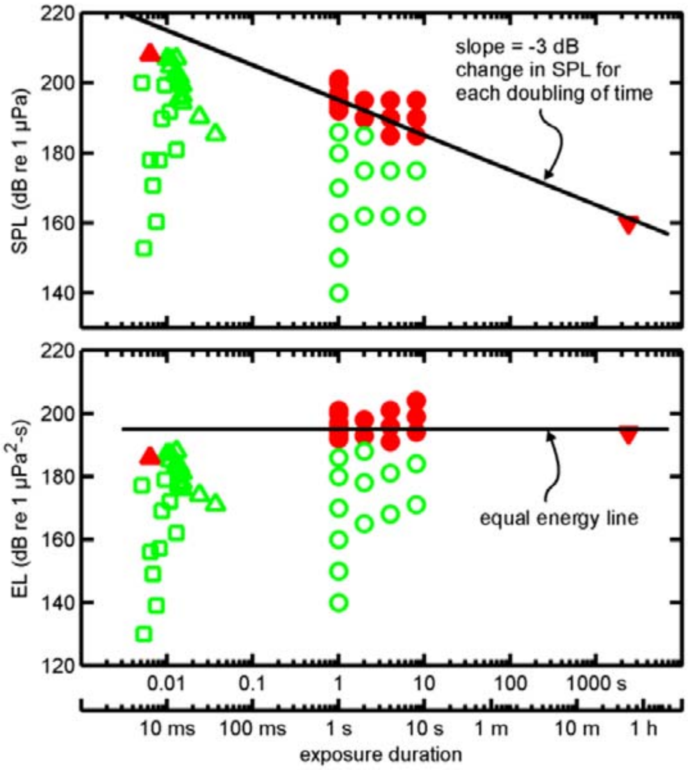
Figure 6-3 shows the existing TTS data for cetaceans (dolphins and beluga whales). Individual exposures are shown in terms of SPL versus exposure duration (upper panel) and EL versus exposure duration (lower panel). Exposures that produced TTS are shown as filled symbols. Exposures that did not produce TTS are represented by open symbols. The squares and triangles represent impulsive test results from Finneran et al., 2000 and 2002, respectively. The circles show the 3, 10, and 20 kHz data from Schlundt et al. (2000) and the results of Finneran et al. (2003). The inverted triangle represents data from Nachtigall et al. (2004).

Figure 6-3 illustrates that the effects of the different sound exposures depend on the SPL and duration. As the duration decreases, higher SPLs are required to cause TTS. In contrast, the ELs required for TTS do not show the same type of variation with exposure duration.

The solid line in the upper panel of Figure 6-3 has a slope of -3 dB per doubling of time. This line passes through the point where the SPL is 195 dB re 1 µPa and the exposure duration is 1 second. Since EL = SPL + $10\log_{10}$ (duration), doubling the duration *increases* the EL by 3 dB. Subtracting 3 dB from the SPL *decreases* the EL by 3 dB. The line with a slope of -3 dB per doubling of time, therefore, represents an *equal energy line*, where all points on the line have the same EL, which is, in this case, 195 dB re 1 µPa^2-s. This line appears in the lower panel as a horizontal line at 195 dB re 1 µPa^2-s. The equal energy line at 195 dB re 1 µPa^2-s fits the tonal and sound data (the nonimpulsive data) very well, despite differences in exposure duration, SPL, experimental methods, and subjects.

In summary, the existing marine mammal TTS data show that, for the species studied and sounds (nonimpulsive) of interest, the following is true:

- The growth and recovery of TTS are comparable to those in land mammals. This means that, as in land mammals, cetacean TSs depend on the amplitude, duration, frequency content, and temporal pattern of the sound exposure. Threshold shifts will generally increase with the amplitude and duration of sound exposure. For continuous sounds, exposures of equal energy will lead to approximately equal effects (Ward, 1997). For intermittent sounds, less TS will occur than from a continuous exposure with the same energy (some recovery will occur between exposures) (Ward, 1997).
- SPL by itself is not a good predictor of onset-TTS, since the amount of TTS depends on both SPL and duration.
- Exposure EL is correlated with the amount of TTS and is a good predictor for onset-TTS for single, continuous exposures with different durations. This agrees with human TTS data presented by Ward et al. (1958, 1959).
- An EL of 195 dB re 1 μPa^2-s is the most appropriate predictor for onset-TTS from a single, continuous exposure.



Legend:	Filled symbol:	Exposure that produced TTS
	Open symbol:	Exposure that did not produce TTS
	Squares:	Impulsive test results from Finneran et al., 2000
	Triangles:	Impulsive test results from Finneran et al., 2002
	Circles:	3-, 10-, and 20-kHz data from Schlundt et al. (2000) and results of Finneran et al. (2003a)
	Inverted triangle:	Data from Nachtigall et al., 2003b

Figure 6-3. Existing TTS Data for Cetaceans

Relationship Between TTS and PTS

Since marine mammal PTS data do not exist, onset-PTS levels for these animals must be estimated using TTS data and relationships between TTS and PTS. Much of the early human TTS work was directed towards relating TTS_2 after 8 hours of sound exposure to the amount of PTS that would exist after years of similar daily exposures (e.g., Kryter et al., 1966). Although it is now acknowledged that susceptibility to PTS cannot be reliably predicted from TTS measurements, TTS data do provide insight into the amount of TS that may be induced without a PTS. Experimental studies of the growth of TTS may also be used to relate changes in exposure level to changes in the amount of TTS induced. Onset-PTS exposure levels may therefore be predicted by:

- Estimating the largest amount of TTS that may be induced without PTS. Exposures causing a TS greater than this value are assumed to cause PTS.
- Estimating the additional exposure, above the onset-TTS exposure, necessary to reach the maximum allowable amount of TTS that, again, may be induced without PTS. This is equivalent to estimating the growth rate of TTS, or how much additional TTS is produced by an increase in exposure level.

Experimentally induced TTSs in marine mammals have generally been limited to around 2 to 10 dB, well below TSs that result in some PTS. Experiments with terrestrial mammals have used much larger TSs and provide more guidance on how high a TS may rise before some PTS results. Early human TTS studies reported complete recovery of TTSs as high as 50 dB after exposure to broadband sound (Ward, 1960; Ward et al., 1958, 1959). Ward et al. (1959) also reported slower recovery times when TTS_2 approached and exceeded 50 dB, suggesting that 50 dB of TTS_2 may represent a "critical" TTS. Miller et al. (1963) found PTS in cats after exposures that were only slightly longer in duration than those causing 40 dB of TTS. Kryter et al. (1966) stated: "A TTS_2 that approaches or exceeds 40 dB can be taken as a signal that danger to hearing is imminent." These data indicate that TSs up to 40 to 50 dB may be induced without PTS, and that 40 dB is a reasonable upper limit for TS to prevent PTS.

The small amounts of TTS produced in marine mammal studies also limit the applicability of these data to estimates of the growth rate of TTS. Fortunately, data do exist for the growth of TTS in terrestrial mammals. For moderate exposure durations (a few minutes to hours), TTS_2 varies with the logarithm of exposure time (Ward et al., 1958, 1959; Quaranta et al., 1998). For shorter exposure durations, the growth of TTS with exposure time appears to be less rapid (Miller, 1974; Keeler, 1976). For very long-duration exposures, increasing the exposure time may fail to produce any additional TTS, a condition known as asymptotic threshold shift (Saunders et al., 1977; Mills et al., 1979).

Ward et al. (1958, 1959) provided detailed information on the growth of TTS in humans. Ward et al. presented the amount of TTS measured after exposure to specific SPLs and durations of broadband sound. Since the relationship between EL, SPL, and duration is known, these same data could be presented in terms of the amount of TTS produced by exposures with different ELs.

Figure 6-4 shows results from Ward et al. (1958, 1959) plotted as the amount of TTS_2 versus the exposure EL. The data in Figure 6-4(a) are from broadband (75 hertz [Hz] to 10 kHz) sound exposures with durations of 12 to 102 minutes (Ward et al., 1958). The symbols represent mean TTS_2 for 13 individuals exposed to continuous sound. The solid line is a linear regression fit to all but the two data points at the lowest exposure EL. The experimental data are fit well by the regression line (R2 = 0.95). These data are important for two reasons: (1) they confirm that the amount of TTS is correlated with the exposure EL; and (2) the slope of the line allows one to estimate the additional amount of TTS produced by an increase in exposure. For example, the slope of the line in Figure 6-4(a) is approximately 1.5 dB TTS_2 per dB of EL. This means that each additional dB of EL produces 1.5 dB of additional TTS_2.

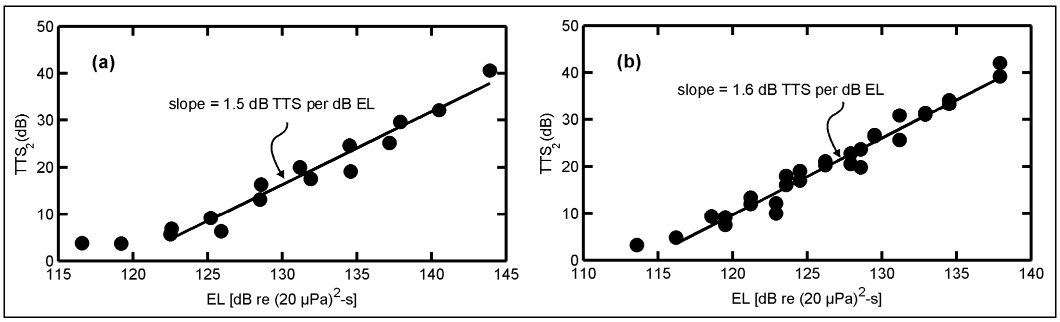


Figure 6-4. Growth of TTS Versus the Exposure EL
(from Ward et al. [1958, 1959])

The data in Figure 6-4(b) are from octave-band sound exposures (2.4 to 4.8 kHz) with durations of 12 to 102 minutes (Ward et al., 1959). The symbols represent mean TTS for 13 individuals exposed to continuous sound. The linear regression was fit to all but the two data points at the lowest exposure EL. The results are similar to those shown in Figure 6-4(a). The slope of the regression line fit to the mean TTS data was 1.6 dB TTS_2/dB EL. A similar procedure was carried out for the remaining data from Ward et al. (1959), with comparable results. Regression lines fit to the TTS versus EL data had slopes ranging from 0.76 to 1.6 dB TTS_2/dB EL, depending on the frequencies of the sound exposure and hearing test.

An estimate of 1.6 dB TTS_2 per dB increase in exposure EL is the upper range of values from Ward et al. (1958, 1959) and gives the most conservative estimate; it predicts a larger amount of TTS from the same exposure compared to the lines with smaller slopes. The difference between onset-TTS (6 dB) and the upper limit of TTS before PTS (40 dB) is 34 dB. To move from onset-TTS to onset-PTS, therefore, requires an increase in EL of 34 dB divided by 1.6 dB/dB, or approximately 21 dB. An estimate of 20 dB between exposures sufficient to cause onset-TTS and those capable of causing onset-PTS is a reasonable approximation. To summarize:

- In the absence of marine mammal PTS data, onset-PTS exposure levels may be estimated from marine mammal TTS data and PTS/TTS relationships observed in terrestrial mammals. This involves:
- Estimating the largest amount of TTS that may be induced without PTS. Exposures causing a TS greater than this value are assumed to cause PTS.
- Estimating the growth rate of TTS, i.e., determining how much additional TTS is produced by an increase in exposure level.

- A variety of terrestrial mammal data sources point toward 40 dB as a reasonable estimate of the largest amount of TS that may be induced without PTS. A conservative estimate is that continuous-type exposures producing TSs of 40 dB or more always result in some amount of PTS.
- Data from Ward et al. (1958, 1959) reveal a linear relationship between TTS2 and exposure EL. A 1.6 dB TTS2 per dB increase in EL is a conservative estimate of how much additional TTS is produced by an increase in exposure level for continuous-type sounds.
- There is a 34 dB TS difference between onset-TTS (6 dB) and onset-PTS (40 dB). The additional exposure above onset-TTS that is required to reach PTS is therefore 34 dB divided by 1.6 dB/dB, or approximately 21 dB.
- Exposures with ELs 20 dB above those producing TTS may be assumed to produce a PTS. This number is used as a conservative simplification of the 21 dB number derived above.

Threshold Levels for Harassment from Physiological Effects

For this specified action, sound exposure thresholds for TTS and PTS are as presented in the following box:

195 dB re 1 µPa^2-s received EL for TTS
215 dB re 1 µPa^2-s received EL for PTS

Marine mammals predicted to receive an accumulated sound exposure with EL of 215 dB re 1 µPa^2-s or greater are assumed to experience PTS and are counted as Level A harassment exposures. Marine mammals predicted to receive a sound exposure with EL greater than or equal to 195 dB re 1 µPa^2-s but less than 215 dB re 1 µPa^2-s are assumed to experience TTS and are counted as Level B harassment exposures.

The TTS threshold is primarily based on the cetacean TTS data from Schlundt et al. (2000). Since these tests used short-duration tones similar to sonar pings, they are the most directly relevant data. The mean exposure EL required to produce onset-TTS in these tests was 195 dB re 1 µPa^2-s. This result is corroborated by the short-duration tone data of Finneran et al. (2000 and 2003) and the long-duration sound data from Nachtigall et al. (2003a, 2004). Together, these data demonstrate that TTS in cetaceans is correlated with the received EL and that onset-TTS exposures are fit well by an equal-energy line passing through 195 dB re 1 µPa^2-s.

The PTS threshold is based on a 20 dB increase in exposure EL over that required for onset-TTS. The 20 dB value is based on estimates from terrestrial mammal data of PTS occurring at 40 dB or more of TS, and on TS growth occurring at a rate of 1.6 dB/dB increase in exposure EL. This is conservative because: (1) 40 dB of TS is actually an upper limit for TTS used to approximate onset-PTS, and (2) the 1.6 dB/dB growth rate is the highest observed in the data from Ward et al. (1958, 1959).

Use of EL for Physiological Effect Thresholds

Effect thresholds are expressed in terms of total received EL. Energy flux density is a measure of the flow of sound energy through an area. Marine and terrestrial mammal data show that, for continuous-type sounds of interest, TTS and PTS are more closely related to the energy in the sound exposure than to the exposure SPL.

The EL for each individual ping is calculated from the following equation:

$$EL = SPL + 10\log_{10}(\text{duration})$$

The EL includes both the ping SPL and duration. Longer-duration pings and/or higher-SPL pings will have a higher EL.

If an animal is exposed to multiple pings, the energy flux density in each individual ping is summed to calculate the total EL. Since mammalian TS data show less effect from intermittent exposures compared to continuous exposures with the same energy (Ward, 1997), basing the effect thresholds on the total received EL is a conservative approach for treating multiple pings; in reality, some recovery will occur between pings and lessen the effect of a particular exposure. Therefore, estimates are conservative because recovery is not taken into account; intermittent exposures are considered comparable to continuous exposures.

The total EL depends on the SPL, duration, and number of pings received. The TTS and PTS thresholds do not imply any specific SPL, duration, or number of pings. The SPL and duration of each received ping are used to calculate the total EL and determine whether the received EL meets or exceeds the effect thresholds. For example, the TTS threshold would be reached through any of the following exposures:

- A single ping with SPL = 195 dB re 1 µPa and duration = 1 second.
- Two pings with SPL = 189 dB re 1 µPa and duration = 2 seconds.

Summary of Criteria and Thresholds for Physiological Effects

PTS and TTS are used as the criteria for physiological effects resulting in injury (Level A harassment) and disturbance (Level B harassment), respectively. Sound exposure thresholds for TTS and PTS are 195 dB re 1 μPa^2-s received EL for TTS and 215 dB re 1 μPa^2-s received EL for PTS. The TTS threshold is primarily based on cetacean TTS data from Schlundt et al. (2000). Since these tests used short-duration tones similar to sonar pings, they are the most directly relevant data. The PTS threshold is based on a 20 dB increase in exposure EL over that required for onset-TTS. The 20 dB value is based on extrapolations from terrestrial mammal data indicating that PTS occurs at 40 dB or more of TS, and that TS growth occurring at a rate of approximately 1.6 dB/dB increase in exposure EL.

Analytical Methodology – MMPA Behavioral Harassment For MFA/HFA Sources

Background

Based on available evidence, marine animals are likely to exhibit any of a suite of potential behavioral responses or combinations of behavioral responses upon exposure to sonar transmissions. Potential behavioral responses include, but are not limited to: avoiding exposure or continued exposure; behavioral disturbance (including distress or disruption of social or foraging activity); habituation to the sound; becoming sensitized to the sound; or not responding to the sound.

Existing studies of behavioral effects of human-made sounds in marine environments remain inconclusive, partly because many of those studies have lacked adequate controls, applied only to certain kinds of exposures (which are often different from the exposures being analyzed in the study), and had limited ability to detect behavioral changes that may be significant to the biology of the animals that were being observed. These studies are further complicated by the wide variety of behavioral responses marine mammals exhibit and the fact that those responses can vary significantly by species, individuals, and the context of an exposure. In some circumstances, some individuals will continue normal behavioral activities in the presence of high levels of human-made noise. In other circumstances, the same individual or other individuals may avoid an acoustic source at much lower received levels (Richardson et al., 1995; Wartzok et al., 2003). These differences within and between individuals appear to result from a complex interaction of experience, motivation, and learning that are difficult to quantify and predict.

It is possible that some marine mammal behavioral reactions to anthropogenic sound may result in strandings. Several "mass stranding" events—strandings that involve two or more individuals of the same species (excluding a single cow-calf pair)—that have occurred over the past two decades have been associated with naval operations, seismic surveys, and other anthropogenic activities that introduced sound into the marine environment. Sonar exposure has been identified as a contributing cause or factor in five specific mass stranding events: Greece in 1996; the Bahamas in March 2000; Madeira Island, Portugal in 2000; the Canary Islands in 2002, and Spain in 2006 (Advisory Committee Report on Acoustic Impacts on Marine Mammals, 2006).
In these circumstances, exposure to acoustic energy has been considered an indirect cause of the death of marine mammals (Cox et al., 2006). Based on studies of lesions in beaked whales that have stranded in the Canary Islands and Bahamas associated with exposure to naval exercises that involved sonar, several investigators have hypothesized that there are two potential physiological mechanisms that might explain why marine mammals stranded: tissue damage resulting from resonance effects (Ketten, 2005) and tissue damage resulting from "gas and fat embolic syndrome" (Fernandez et al., 2005; Jepson et al., 2003; 2005). It is also likely that stranding is a behavioral response to a sound under certain contextual conditions and that the subsequently observed physiological effects of the strandings (e.g., overheating, decomposition, or internal hemorrhaging from being on shore) were the result of the stranding versus exposure to sonar (Cox et al., 2006).

Methodology for Applying Risk Function

Risk Function Adapted from Feller (1968)

To assess the potential effects on marine mammals associated with active sonar used during training activity the Navy and NMFS applied a risk function that estimates the probability of behavioral responses that NMFS would classify as harassment for the purposes of the MMPA given exposure to specific received levels of MFA sonar. The mathematical function is derived from a solution in Feller (1968) as defined in the SURTASS LFA Sonar Final OEIS/EIS (U.S. Department of the Navy, 2001), and relied on in the Supplemental SURTASS LFA Sonar EIS (U.S. Department of the Navy, 2007a) for the probability of MFA sonar risk for MMPA Level B behavioral harassment with input parameters modified by NMFS for MFA sonar for mysticetes and odontocetes (National Marine Fisheries Service, 2008). The same risk function and input parameters will be applied to high frequency active (HFA) (>10 kHz) sources until applicable data becomes available for high frequency sources.

In order to represent a probability of risk, the function should have a value near zero at very low exposures, and a value near one for very high exposures. One class of functions that satisfies this criterion is cumulative probability distributions, a type of cumulative distribution function. In selecting a particular functional expression for risk, several criteria were identified:

- The function must use parameters to focus discussion on areas of uncertainty;
- The function should contain a limited number of parameters;
- The function should be capable of accurately fitting experimental data; and
- The function should be reasonably convenient for algebraic manipulations.

As described in U.S. Department of the Navy (2001), the mathematical function below is adapted from a solution in Feller (1968).

Where: R = risk (0 – 1.0);
L = Received Level (RL) in dB;
B = basement RL in dB; (120 dB);
K = the RL increment above basement in dB at which there is 50 percent risk;
A = risk transition sharpness parameter (10) (explained in 3.1.4.3).

In order to use this function, the values of the three parameters (B, K, and A) need to be established. As further explained in the section title *Input Parameters for the Risk Function*, the values used in this analysis are based on three sources of data: TTS experiments conducted at SSC and documented in Finneran, et al., (2001, 2003, and 2005; Finneran and Schlundt, 2004); reconstruction of sound fields produced by the USS Shoup associated with the behavioral responses of killer whales observed in Haro Strait and documented in Department of Commerce (National Marine Fisheries Service, 2005); U.S. Department of the Navy (2004); and Fromm (2004a, 2004b); and observations of the behavioral response of North Atlantic right whales exposed to alert stimuli containing mid-frequency components documented in Nowacek et al. (2004). The input parameters, as defined by NMFS, are based on very limited data that represent the best available science at this time.

Data Sources Used for Risk Function

There is widespread consensus that cetacean response to MFA sound signals needs to be better defined using controlled experiments. Navy is contributing to an ongoing behavioral response study in the Bahamas that is anticipated to provide some initial information on beaked whales, the species identified as the most sensitive to MFA sonar. NMFS is leading this international effort with scientists from various academic institutions and research organizations to conduct studies on how marine mammals respond to underwater sound exposures.

Until additional data is available, NMFS and the Navy have determined that the following three data sets are most applicable for the direct use in developing risk function parameters for MFA/HFA sonar. These data sets represent the only known data that specifically relate altered behavioral responses to exposure to MFA sound sources.

<u>Data from SSC's Controlled Experiments:</u> Most of the observations of the behavioral responses of toothed whales resulted from a series of controlled experiments on bottlenose dolphins and beluga whales conducted by researchers at SSC's facility in San Diego, California (Finneran et al., 2001, 2003, 2005; Finneran and Schlundt 2004; Schlundt et al., 2000). In experimental trials with marine mammals trained to perform tasks when prompted, scientists evaluated whether the marine mammals performed these tasks when exposed to mid-frequency tones. Altered behavior during experimental trials usually involved refusal of animals to return to the site of the sound stimulus. This refusal included what appeared to be deliberate attempts to avoid a sound exposure or to avoid the location of the exposure site during subsequent tests. (Schlundt et al., 2000, Finneran et al., 2002) Bottlenose dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 micropascal (μPa) root mean square (rms), and beluga whales did so at received levels of 180 to 196 dB and above. Test animals sometimes vocalized after an exposure to impulsive sound from a seismic watergun (Finneran et al., 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway et al., 1997; Schlundt et al., 2000).

1. Finneran and Schlundt (2004) examined behavioral observations recorded by the trainers or test coordinators during the Schlundt et al. (2000) and Finneran et al. (2001, 2003, 2005) experiments featuring 1-second (sec) tones. These included observations from 193 exposure sessions (fatiguing stimulus level > 141 dB re 1μPa) conducted by Schlundt et al. (2000) and 21 exposure sessions conducted by Finneran et al. (2001, 2003, 2005). The observations were made during exposures to sound sources at 0.4 kHz, 3 kHz, 10 kHz, 20 kHz, and 75 kHz. The TTS experiments that supported Finneran and Schlundt (2004) are further explained below:
    a. Schlundt et al. (2000) provided a detailed summary of the behavioral responses of trained marine mammals during TTS tests conducted at SSC San Diego with 1-sec tones. Schlundt et al. (2000) reported eight individual TTS experiments. Fatiguing stimuli durations were 1-sec; exposure frequencies were 0.4 kHz, 3 kHz, 10 kHz, 20 kHz and 75 kHz. The experiments were conducted in San Diego Bay. Because of the variable ambient noise in the bay, low-level broadband masking noise was used to keep hearing thresholds consistent despite fluctuations in the ambient noise. Schlundt et al. (2000) reported that "behavioral alterations," or deviations from the behaviors the

animals being tested had been trained to exhibit, occurred as the animals were exposed to increasing fatiguing stimulus levels.

b. Finneran et al. (2001, 2003, 2005) conducted TTS experiments using tones at 3 kHz. The test method was similar to that of Schlundt et al. (2000) except the tests were conducted in a pool with very low ambient noise level (below 50 dB re 1 μPa/hertz [Hz]), and no masking noise was used. Two separate experiments were conducted using 1-sec tones. In the first, fatiguing sound levels were increased from 160 to 201 dB SPL. In the second experiment, fatiguing sound levels between 180 and 200 dB re 1 μPa were randomly presented.

<u>Data from Studies of Baleen (Mysticetes) Whale Responses:</u> The only mysticete data available resulted from a field experiments in which baleen whales (mysticetes) were exposed to a range frequency sound sources from 120 Hz to 4500 Hz (Nowacek et al., 2004). An alert stimulus, with a mid-frequency component, was the only portion of the study used to support the risk function input parameters.

2. Nowacek et al. (2004) documented observations of the behavioral response of North Atlantic right whales exposed to alert stimuli containing mid-frequency components. To assess risk factors involved in ship strikes, a multi-sensor acoustic tag was used to measure the responses of whales to passing ships and experimentally tested their responses to controlled sound exposures, which included recordings of ship noise, the social sounds of conspecifics and a signal designed to alert the whales. The alert signal was 18-minutes of exposure consisting of three 2-minute signals played sequentially three times over. The three signals had a 60 percent duty cycle and consisted of: (1) alternating 1-sec pure tones at 500 Hz and 850 Hz; (2) a 2-sec logarithmic down-sweep from 4,500 Hz to 500 Hz; and (3) a pair of low (1,500 Hz)-high (2,000 Hz) sine wave tones amplitude modulated at 120 Hz and each 1-sec long. The purposes of the alert signal were (a) to provoke an action from the whales via the auditory system with disharmonic signals that cover the whales estimated hearing range; (b) to maximize the signal to noise ratio (obtain the largest difference between background noise) and c) to provide localization cues for the whale. Five out of six whales reacted to the signal designed to elicit such behavior. Maximum received levels ranged from 133 to 148 dB re 1μPa.

<u>Observations of Killer Whales in Haro Strait in the Wild:</u> In May 2003, killer whales (Orcinus orca) were observed exhibiting behavioral responses while the USS Shoup was engaged in MFA sonar operations in the Haro Strait in the vicinity of Puget Sound, Washington. Although these observations were made in an uncontrolled environment, the sound field that may have been associated with the sonar operations had to be estimated, and the behavioral observations were reported for groups of whales, not individual whales, the observations associated with the USS Shoup provide the only data set available of the behavioral responses of wild, non-captive animal upon exposure to the AN/SQS-53 MFA sonar.

3. U.S. Department of Commerce (National Marine Fisheries, 2005); U.S. Department of the Navy (2004); Fromm (2004a, 2004b) documented reconstruction of sound fields

produced by the USS Shoup associated with the behavioral response of killer whales observed in Haro Strait. Observations from this reconstruction included an approximate closest approach time which was correlated to a reconstructed estimate of received level at an approximate whale location (which ranged from 150 to 180 dB), with a mean value of 169.3 dB.

Limitations of the Risk Function Data Sources

There are significant limitations and challenges to any risk function derived to estimate the probability of marine mammal behavioral responses; these are largely attributable to sparse data. Ultimately there should be multiple functions for different marine mammal taxonomic groups, but the current data are insufficient to support them. The goal is unquestionably that risk functions be based on empirical measurement.

The risk function presented here is based on three data sets that NMFS and Navy have determined are the best available science at this time. The Navy and NMFS acknowledge each of these data sets has limitations. However, this risk function, if informed by the limited available data relevant to the MFA sonar application, has the advantages of simplicity and the fact that there is precedent for its application and foundation in marine mammal research.
While NMFS considers all data sets as being weighted equally in the development of the risk function, the Navy believes the SSC San Diego data is the most rigorous and applicable for the following reasons:

- The data represents the only source of information where the researchers had complete control over and ability to quantify the noise exposure conditions.
- The altered behaviors were identifiable due to long term observations of the animals.
- The fatiguing noise consisted of tonal exposures with limited frequencies contained in the MFA sonar bandwidth.

However, the Navy and NMFS do agree that the following are limitations associated with the three data sets used as the basis of the risk function:

- The three data sets represent the responses of only four species: trained bottlenose dolphins and beluga whales, North Atlantic right whales in the wild and killer whales in the wild.
- None of the three data sets represent experiments designed for behavioral observations of animals exposed to MFA sonar.
- The behavioral responses of marine mammals that were observed in the wild are based solely on an estimated received level of sound exposure; they do not take into consideration (due to minimal or no supporting data):
  - Potential relationships between acoustic exposures and specific behavioral activities (e.g., feeding, reproduction, changes in diving behavior, etc.), variables such as bathymetry, or acoustic waveguides; or
  - Differences in individuals, populations, or species, or the prior experiences, reproductive state, hearing sensitivity, or age of the marine mammal.

<u>SSC San Diego Trained Bottlenose Dolphins and Beluga Data Set:</u>

- The animals were trained animals in captivity; therefore, they may be more or less sensitive than cetaceans found in the wild (Domjan, 1998).
- The tests were designed to measure TTS, not behavior.
- Because the tests were designed to measure TTS, the animals were exposed to much higher levels of sound than the baseline risk function (only two of the total 193 observations were at levels below 160 dB re 1 μPa2-s).
- The animals were not exposed in the open ocean but in a shallow bay or pool.

<u>North Atlantic Right Whales in the Wild Data Set:</u>

- The observations of behavioral response were from exposure to alert stimuli that contained mid-frequency components but was not similar to a MFA sonar ping. The alert signal was 18 minutes of exposure consisting of three 2-minute signals played sequentially three times over. The three signals had a 60 percent duty cycle and consisted of: (1) alternating 1-sec pure tones at 500 Hz and 850 Hz; (2) a 2-sec logarithmic down-sweep from 4,500 Hz to 500 Hz; and (3) a pair of low (1,500 Hz)-high (2,000 Hz) sine wave tones amplitude modulated at 120 Hz and each 1-sec long. This 18-minute alert stimuli is in contrast to the average 1-sec ping every 30 sec in a comparatively very narrow frequency band used by military sonar.
- The purpose of the alert signal was, in part, to provoke an action from the whales through an auditory stimulus.

<u>Killer Whales in the Wild Data Set:</u>

- The observations of behavioral harassment were complicated by the fact that there were other sources of harassment in the vicinity (other vessels and their interaction with the animals during the observation).
- The observations were anecdotal and inconsistent. There were no controls during the observation period, with no way to assess the relative magnitude of the any observed response as opposed to baseline conditions.

Input Parameters for the Risk Function

The values of B, K, and A need to be specified in order to utilize the risk function defined in the previous section titled *Methodology for Applying Risk Function*. The risk continuum function approximates the risk function in a manner analogous to pharmacological risk assessment. In this case, the risk function is combined with the distribution of sound exposure levels to estimate aggregate impact on an exposed population.

Basement Value for Risk — The B Parameter

The B parameter defines the basement value for risk, below which the risk is so low that calculations are impractical. This 120 dB level is taken as the estimate received level (RL) below which the risk of significant change in a biologically important behavior approaches zero for the MFA/HFA sonar risk assessment. This level is based on a broad overview of the levels at which multiple species have been reported responding to a variety of sound sources, both mid-frequency and other, was recommended by the NMFS, and has been used in other publications.

The Navy recognizes that for actual risk of changes in behavior to be zero, the signal-to-noise ratio of the animal must also be zero. However, the present convention of ending the risk calculation at 120 dB for MFA/HFA sonar has a negligible impact on the subsequent calculations, because the risk function does not attain appreciable values at received levels that low.

The K Parameter

NMFS and the Navy used the mean of the following values to define the midpoint of the function: (1) the mean of the lowest received levels (185.3 dB) at which individuals responded with altered behavior to 3 kHz tones in the SSC data set; (2) the estimated mean received level value of 169.3 dB produced by the reconstruction of the USS Shoup incident in which killer whales exposed to MFA sonar (range modeled possible received levels: 150 to 180 dB); and (3) the mean of the 5 maximum received levels at which Nowacek et al. (2004) observed significantly altered responses of right whales to the alert stimuli than to the control (no input signal) is 139.2 dB SPL. The arithmetic mean of these three mean values is 165 dB SPL. The value of K is the difference between the value of B (120 dB SPL) and the 50 percent value of 165 dB SPL; therefore, K=45.

Risk Transition – The A Parameter

The A parameter controls how rapidly risk transitions from low to high values with increasing receive level. As A increases, the slope of the risk function increases. For very large values of A, the risk function can approximate a threshold response or step function. NMFS has recommended that the Navy use A=10 as the value for odontocetes (Figure 6-5) (National Marine Fisheries Service, 2008). This is the same value of A that was used for the SURTASS LFA sonar analysis. As stated in the SURTASS LFA Sonar Final OEIS/EIS (U.S. Department of the Navy, 2001), the value of A=10 produces a curve that has a more gradual transition than the curves developed by the analyses of migratory gray whale studies (Malme et al., 1984). The choice of a more gradual slope than the empirical data was consistent with other decisions for the SURTASS LFA Sonar Final OEIS/EIS to make conservative assumptions when extrapolating from other data sets (see Subchapter 1.4.3 and Appendix D of the SURTASS LFA Sonar EIS).

Based on NMFS' direction, the Navy will use a value of A=8 for mysticetes to allow for greater consideration of potential harassment at the lower received levels based on Nowacek et al., 2004 (Figure 6-6). (National Marine Fisheries Service, 2008)

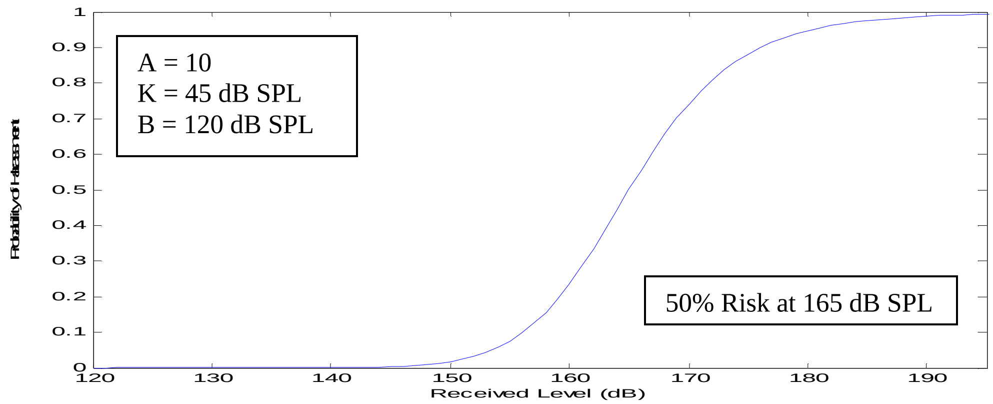


Figure 6-5. Risk Function Curve for Odontocetes (Toothed Whales)

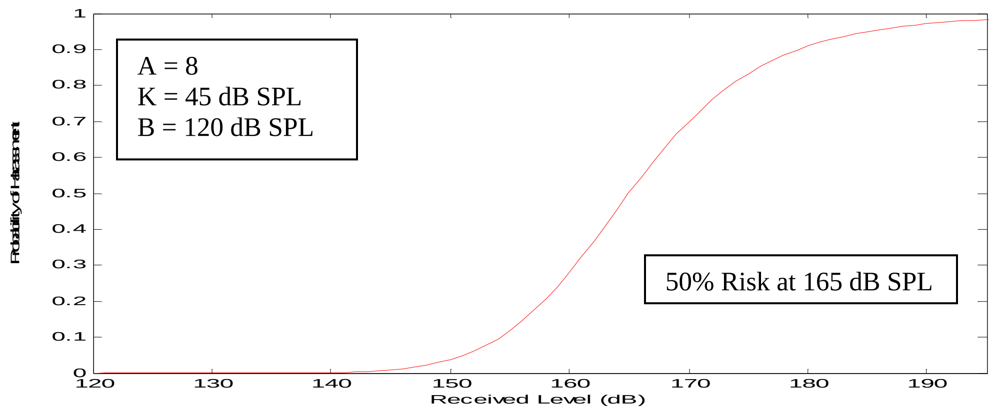


Figure 6-6. Risk Function Curve for Mysticetes (Baleen Whales)

Basic Application of the Risk Function

Relation of the Risk Function to the Current Regulatory Scheme

The risk function is used to estimate the percentage of an exposed population that is likely to exhibit behaviors that would qualify as harassment (as that term is defined by the MMPA applicable to military readiness activities, such as the Navy's testing and training with MFA sonar) at a given received level of sound. For example, at 165 dB SPL (dB re: 1µPa rms), the risk (or probability) of harassment is defined according to this function as 50 percent, and Navy/NMFS applies that by estimating that 50 percent of the individuals exposed at that received level are likely to respond by exhibiting behavior that NMFS would classify as behavioral harassment. The risk function is not applied to individual animals, only to exposed populations.

The data used to produce the risk function were compiled from four species that had been exposed to sound sources in a variety of different circumstances. As a result, the risk function represents a general relationship between acoustic exposures and behavioral responses that is then applied to specific circumstances. That is, the risk function represents a relationship that is deemed to be generally true, based on the limited, best-available science, but may not be true in specific circumstances. In particular, the risk function, as currently derived, treats the received level as the only variable that is relevant to a marine mammal's behavioral response. However, we know that many other variables—the marine mammal's gender, age, and prior experience;

the activity it is engaged in during an exposure event, its distance from a sound source, the number of sound sources, and whether the sound sources are approaching or moving away from the animal—can be critically important in determining whether and how a marine mammal will respond to a sound source (Southall et al., 2007). The data that are currently available do not allow for incorporation of these other variables in the current risk functions; however, the risk function represents the best use of the data that are available.

As more specific and applicable data become available, NMFS can use these data to modify the outputs generated by the risk function to make them more realistic (and ultimately, data may exist to justify the use of additional, alternate, or multi-variate functions). As mentioned above, it is known that the distance from the sound source and whether it is perceived as approaching or moving away can affect the way an animal responds to a sound (Wartzok et al., 2003). Those distances would influence whether those animals might perceive the sound source as a potential threat, and their behavioral responses to that threat. Though there are data showing marine mammal responses to sound sources at that received level, NMFS does not currently have any data that describe the response of marine mammals to sounds at that distance (or to other contextual aspects of the exposure, such as the presence of higher frequency harmonics), much less data that compare responses to similar sound levels at varying distances. However, if data were to become available that suggested animals were less likely to respond (in a manner NMFS would classify as harassment) to certain levels beyond certain distances, or that they were more likely to respond at certain closer distances, Navy will re-evaluate the risk function to try to incorporate any additional variables into the “take” estimates.

Last, pursuant to the MMPA, an applicant is required to estimate the number of animals that will be “taken” by their activities. This estimate informs the analysis that NMFS must perform to determine whether the activity will have a “negligible impact” on the species or stock. Level B (behavioral) harassment occurs at the level of the individual(s) and does not assume any resulting population-level consequences, though there are known avenues through which behavioral disturbance of individuals can result in population-level effects. Alternately, a negligible impact finding is based on the lack of likely adverse effects to annual rates of recruitment or survival (i.e., population-level effects). An estimate of the number of Level B harassment takes, alone, is not enough information on which to base an impact determination. In addition to considering estimates of the number of marine mammals that might be “taken” through harassment, NMFS must consider other factors, such as the nature of any responses (their intensity, duration, etc.), the context of any responses (critical reproductive time or location, migration, etc.), or any of the other variables mentioned in the first paragraph (if known), as well as the number and nature of estimated Level A takes, the number of estimated mortalities, and effects on habitat. For example, in the case of sonar usage in the NSWC PCD Study Area, due to the nature of sound propagation, a portion of the animals that are likely to be “taken” through behavioral harassment are expected to be exposed at relatively low received levels (120-135 dB) where the significance of those responses would be reduced because of the distance from a sound source. Alternatively, a portion of the animals that are expected to be “taken” through behavioral harassment are expected to occur when animals are exposed to higher received levels, such as those approaching the onset of TTS (180-195 dB). Generally speaking, Navy and NMFS anticipate more severe effects from takes resulting from exposure to higher received levels (though this is in no way a strictly linear relationship throughout species, individuals, or circumstances) and less severe effects from takes resulting from exposure to lower received levels.

It is worth noting that Navy and NMFS would expect a relatively large portion of the animals that are likely to be "taken" in the NSWC PCD Study Area (those that occur when an animal is exposed to the levels at the bottom of the risk function), to exhibit behavioral responses that are less likely to adversely affect the longevity, survival, or reproductive success of the animals that might be exposed, based on received level, and the fact that the exposures will occur in the absence of some of the other contextual variables that would likely be associated with increased severity of effects, such as the proximity of the sound source(s) or the proximity of other vessels, aircraft, submarines, etc. maneuvering in the vicinity of the exercise. NMFS will consider all available information (other variables, etc.), but all else being equal, takes that result from exposure to lower received levels and at greater distances from the exercises would be less likely to contribute to population level effects.

Analytical Framework for Assessing Marine Mammal Response to Active Sonar

Marine mammals respond to various types of man-made sounds introduced into the ocean environment. Responses are typically subtle and can include shorter surfacings, shorter dives, fewer blows per surfacing, longer intervals between blows (breaths), ceasing or increasing vocalizations, shortening or lengthening vocalizations, and changing frequency or intensity of vocalizations (National Research Council of the National Academies [NRC], 2005). However, it is not known how these responses relate to significant effects (e.g., long-term effects or population consequences) (NRC, 2005). Assessing whether a sound may disturb or injure a marine mammal involves understanding the characteristics of the acoustic sources, the marine mammals that may be present in the vicinity of the sound, and the effects that sound may have on the physiology and behavior of those marine mammals. The Navy enlisted the expertise of NMFS as the cooperating agency in the preparation of this LOA.

In estimating the potential for marine mammals to be exposed to an acoustic source, the following actions were completed:

- Evaluated potential effects within the context of existing and current regulations, thresholds, and criteria.
- Identified all acoustic sources that will be used during active sonar activities.
- Identified the location, season, and time of the action to determine which marine mammal species are likely to be present.
- Determined the estimated number of marine mammals (i.e., density) of each species that will likely be present in the NSWC PCD Study Area during active sonar activities.
- Applied the applicable acoustic threshold criteria to the predicted sound exposures from the proposed activity. The results of this effort were then evaluated to determine whether the predicted sound exposures from the acoustic model might be considered harassment.
- Considered potential harassment within the context of the affected marine mammal population, stock, or species to assess potential population viability. Particular focus on recruitment and survival are provided to analyze whether the effects of the action can be considered to have negligible effects to species or stocks.

The following flow chart (Figure 6-7) is a representation of the general analytical framework utilized in applying specific thresholds. The framework presented in the flow chart is organized from left to right and is compartmentalized according to the phenomena that occur within each. These include the physics of sound propagation (Physics), the potential physiological processes associated with sound exposure (Physiology), the potential behavioral processes that might be affected as a function of sound exposure (Behavior), and the immediate impacts these changes may have on functions the animal is engaged in at the time of exposure (Life Function – Proximate). These compartmentalized effects are extended to longer-term life functions (Life Function – Ultimate) and into population and species effects. Throughout the flow chart, dotted and solid lines are used to connect related events. Solid lines designate those effects that "will" happen; dotted lines designate those that "might" happen but must be considered (including those hypothesized to occur but for which there is no direct evidence).

Some boxes contained within the flow chart are colored according to how they relate to the definitions of harassment under the MMPA. Red boxes correspond to events that are injurious. By prior ruling and usage, these events would be considered as Level A harassment under the MMPA. Yellow boxes correspond to events that have the potential to qualify as Level B harassment under the MMPA. Based on prior ruling, the specific instance of TTS is considered as Level B harassment. Boxes that are shaded from red to yellow have the potential for injury and behavioral disturbance.

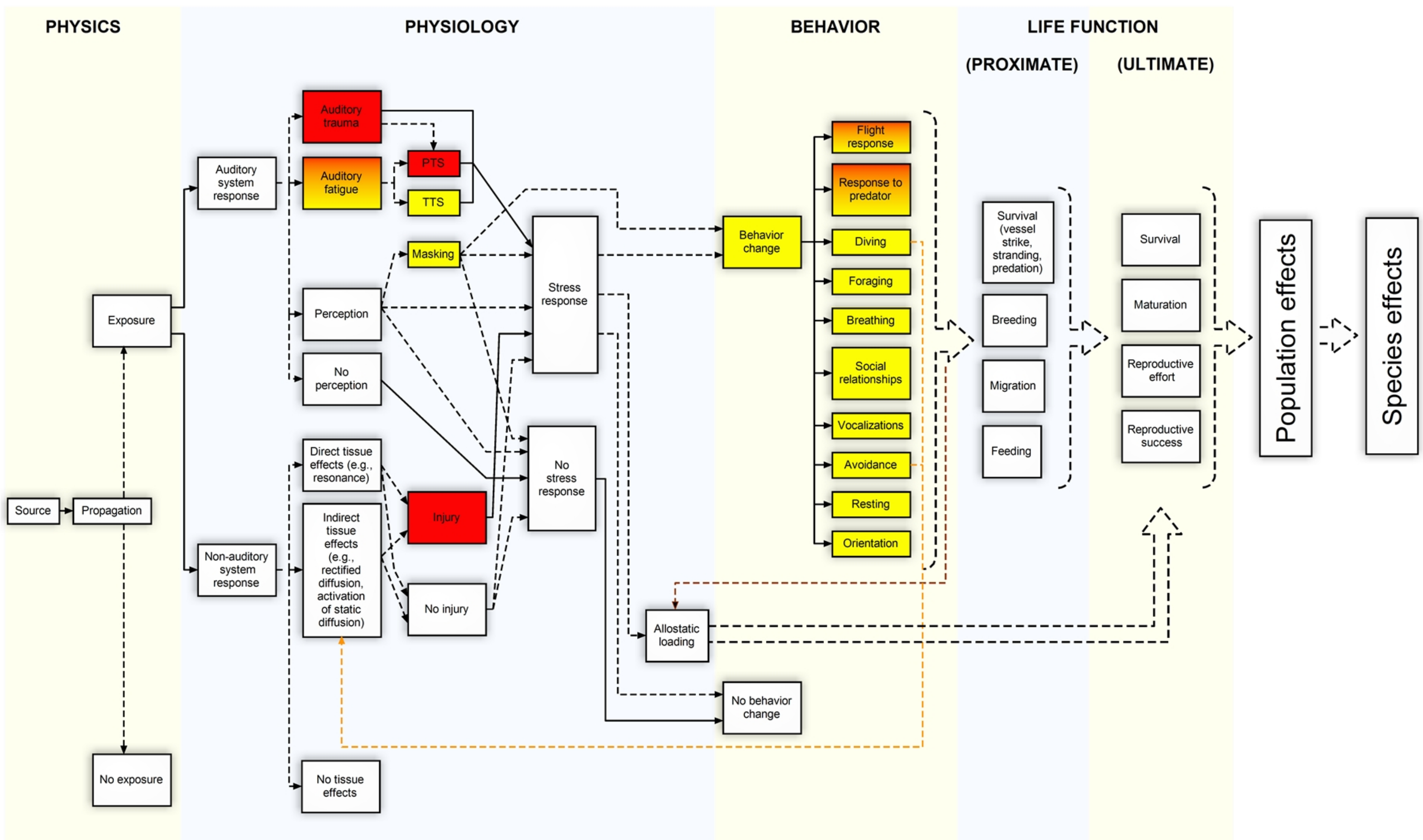


Figure 6-7. Analytical Framework Flow Chart

Physics

Starting with a sound source, the attenuation of an emitted sound due to propagation loss is determined. Uniform animal distribution is overlaid onto the calculated sound fields to assess if animals are physically present at sufficient received sound levels (e.g., above ambient) to be considered "exposed" to the sound. If the animal is determined to be exposed, two possible scenarios must be considered with respect to the animal's physiology, effects on the auditory system and effects on non-auditory system tissues. These are not independent pathways and both must be considered since the same sound could affect both auditory and nonauditory tissues. Note that the model does not account for any animal response; rather, the animals are considered stationary, accumulating energy until the threshold is tripped.

Physiology

Potential impacts to the auditory system are assessed by considering the characteristics of the received sound (e.g., amplitude, frequency, duration) and the sensitivity/susceptibility of the exposed animals. Some of these assessments can be numerically based (e.g., TTS, PTS, perception). Others will be necessarily qualitative, due to lack of information, or will need to be extrapolated from other species for which information exists. Potential physiological responses to the sound exposure are ranked in descending order, with the most severe impact (auditory trauma) occurring at the top and the least severe impact (the sound is not perceived) occurring at the bottom.

1. Auditory trauma represents direct mechanical injury to hearing-related structures, including tympanic membrane rupture, disarticulation of the middle ear ossicles, and trauma to the inner ear structures such as the organ of Corti and the associated hair cells. Auditory trauma is always injurious but could be temporary and not result in PTS. Auditory trauma is always assumed to result in a stress response.

2. Auditory fatigue refers to a loss of hearing sensitivity after sound stimulation. The loss of sensitivity persists, sometimes long after, the cessation of the sound. The mechanisms responsible for auditory fatigue differ from auditory trauma and would primarily consist of metabolic exhaustion of the hair cells and cochlear tissues. The features of the exposure (e.g., amplitude, frequency, duration, temporal pattern) and the individual animal's susceptibility would determine the severity of fatigue and whether the effects were temporary (TTS) or permanent (PTS). Auditory fatigue (PTS or TTS) is always assumed to result in a stress response.

3. Perception – Sounds with sufficient amplitude and duration to be detected among the background ambient noises are considered to be "perceived." This category includes sounds from the threshold of audibility through the normal dynamic range of hearing (i.e., not capable of producing fatigue). To determine whether an animal perceives the sound, the received level, frequency, and duration of the sound are compared to what is known of the species' hearing sensitivity.

   Since audible sounds may interfere with an animal's ability to detect other sounds at the same time, perceived sounds have the potential to result in auditory masking. Unlike auditory fatigue, which always results in a stress response because the sensory tissues are being stimulated beyond their normal physiological range, masking may or may not result in a stress response, depending on the degree and duration of the masking effect. Masking may also result in a unique circumstance where an animal's ability to detect other sounds is compromised without the animal's knowledge. This could conceivably result in sensory impairment and subsequent behavior change; in this case, the change in behavior is the lack of a response that would normally be made if sensory impairment did not occur. For this reason, masking also may lead directly to behavior change without first causing a stress response.

The features of perceived sound (e.g., amplitude, duration, temporal pattern) are also used to judge whether the sound exposure is capable of producing a stress response. Factors to consider in this decision include the probability of the animal being naïve or experienced with the sound (i.e., what are the known/unknown consequences of the exposure).

4. Not perceived – The received level is not of sufficient amplitude, frequency, and duration to be perceptible by the animal. By extension, this does not result in a stress response.

Potential impacts to tissues other than those related to the auditory system are assessed by considering the characteristics of the sound (e.g., amplitude, frequency, duration) and the known or estimated response characteristics of nonauditory tissues. Some of these assessments can be numerically based (e.g., exposure required for rectified diffusion). Others will be necessarily qualitative, due to lack of information. Each of the potential responses may or may not result in a stress response.

1. Direct tissue effects – Direct tissue responses to sound stimulation may range from tissue shearing (injury) to mechanical vibration with no resulting injury. Any tissue injury would produce a stress response, whereas noninjurious stimulation may or may not.

2. Indirect tissue effects – Based on the amplitude, frequency, and duration of the sound, it must be assessed whether exposure is sufficient to indirectly affect tissues. For example, the hypothesis that rectified diffusion occurs is based on the idea that bubbles that naturally exist in biological tissues can be stimulated to grow by an acoustic field. Under this hypothesis, one of three things could happen: (1) bubbles grow to the extent that tissue hemorrhage occurs (injury); (2) bubbles develop to the extent that a complement immune response is triggered or nervous tissue is subjected to enough localized pressure that pain or dysfunction occurs (a stress response without injury); or (3) the bubbles are cleared by the lung without negative consequence to the animal. The probability of rectified diffusion, or any other indirect tissue effect, will necessarily be based on what is known about the specific process involved.

3. No tissue effects – The received sound is insufficient to cause either direct (mechanical) or indirect effects to tissues. No stress response occurs.

The Stress Response

The acoustic source is considered a potential stressor if, by its action on the animal, via auditory or nonauditory means, it may produce a stress response in the animal. The term "stress" has taken on an ambiguous meaning in the scientific literature, but with respect to Figure 6-7 and the later discussions of allostasis and allostatic loading, the term "stress response" will refer to an increase in energetic expenditure that results from exposure to the stressor and which is predominantly characterized by either the stimulation of the sympathetic nervous system (SNS) or the hypothalamic-pituitary-adrenal (HPA) axis (Reeder and Kramer, 2005). The SNS response to a stressor is immediate and acute and is characterized by the release of the catecholamine neurohormones norepinephrine and epinephrine (i.e., adrenaline). These hormones produce elevations in the heart and respiration rate, increase awareness, and increase the availability of glucose and lipids for energy. The HPA response is ultimately defined by increases in the secretion of the glucocorticoid steroid hormones, predominantly cortisol in mammals. The amount of increase in circulating glucocorticoids above baseline may be an indicator of the overall severity of a stress response (Hennessy et al., 1979). Each component of the stress response is variable in time, e.g., adrenalines are released nearly immediately and are used or cleared by the system quickly, whereas cortisol levels may take long periods of time to return to baseline.

The presence and magnitude of a stress response in an animal depends on a number of factors. These include the animal's life history stage (e.g., neonate, juvenile, adult), the environmental conditions, reproductive or developmental state, and experience with the stressor. Not only will these factors be subject to individual variation, but they will also vary within an individual over time. In considering potential stress responses of marine mammals to acoustic stressors, each of these should be considered. For example, is the acoustic stressor in an area where animals engage in breeding activity? Are animals in the region resident and likely to have experience with the stressor (i.e., repeated exposures)? Is the region a foraging ground or are the animals passing through as transients? What is the ratio of young (naïve) to old (experienced) animals in the population? It is unlikely that all such questions can be answered from empirical data; however, they should be addressed in any qualitative assessment of a potential stress response as based on the available literature.

The stress response may or may not result in a behavioral change, depending on the characteristics of the exposed animal. However, provided a stress response occurs, we assume that some contribution is made to the animal's allostatic load. Allostasis is the ability of an animal to maintain stability through change by adjusting its physiology in response to both predictable and unpredictable events (McEwen and Wingfield, 2003). The same hormones associated with the stress response vary naturally throughout an animal's life, providing support for particular life history events (e.g., pregnancy) and predictable environmental conditions (e.g., seasonal changes). The allostatic load is the cumulative cost of allostasis incurred by an animal and is generally characterized with respect to an animal's energetic expenditure. Perturbations to an animal that may occur with the presence of a stressor, either biological (e.g., predator) or anthropogenic (e.g., construction), can contribute to the allostatic load (Wingfield, 2003). Additional costs are cumulative and additions to the allostatic load over time may contribute to reductions in the probability of achieving ultimate life history functions (e.g., survival, maturation, reproductive effort and success) by producing pathophysiological states. The contribution to the allostatic load from a stressor requires estimating the magnitude and duration of the stress response, as well as any secondary contributions that might result from a change in behavior (see the Behavior section, below).

If the acoustic source does not produce tissue effects, is not perceived by the animal, or does not produce a stress response by any other means, Figure 6-7 assumes that the exposure does not contribute to the allostatic load. Additionally, without a stress response or auditory masking, it is assumed that there can be no behavioral change. Conversely, any immediate effect of exposure that produces an injury (i.e., red boxes on the flow chart in Figure 6-7) is assumed to also produce a stress response and contribute to the allostatic load.

Behavior

Acute stress responses may or may not cause a behavioral reaction. However, all changes in behavior are expected to result from an acute stress response. This expectation is based on the idea that some sort of physiological trigger must exist to change any behavior that is already being performed. An exception to this rule is the case of masking. The presence of a masking sound may not produce a stress response, but may interfere with the animal's ability to detect and discriminate biologically relevant signals. The inability to detect and discriminate biologically relevant signals hinders the potential for normal behavioral responses to auditory cues and is thus considered a behavioral change.

Numerous behavioral changes can occur as a result of stress response, and Figure 6-7 lists only those that might be considered the most common types of response for a marine animal. For each potential behavioral change, the magnitude in the change and the severity of the response needs to be estimated. Certain conditions, such as stampeding (i.e., flight response) or a response to a predator, might have a probability of resulting in injury. For example, a flight response, if significant enough, could produce a stranding event. Under the MMPA, such an event would be considered a Level A harassment. Each altered behavior may also have the potential to disrupt biologically significant events (e.g., breeding or nursing) and may need to be qualified as Level B harassment. All behavioral disruptions have the potential to contribute to the allostatic load. This secondary potential is signified by the feedback from the collective behaviors to allostatic loading.

Special considerations are given to the potential for avoidance and disrupted diving patterns. Due to past incidents of beaked whale strandings associated with sonar operations, feedback paths are provided between avoidance and diving and indirect tissue effects. This feedback accounts for the hypothesis that variations in diving behavior and/or avoidance responses can possibly result in nitrogen tissue supersaturation and nitrogen off-gassing, possibly to the point of deleterious vascular bubble formation. Although hypothetical in nature, the potential process is currently popular and hotly debated.

Life Function

Proximate Life Functions

Proximate life history functions are the functions that the animal is engaged in at the time of acoustic exposure. The disruption of these functions, and the magnitude of the disruption, is something that must be considered in determining how the ultimate life history functions are affected. Consideration of the magnitude of the impact to each of the proximate life history functions is dependent upon the life stage of the animal. For example, an animal on a breeding ground that is sexually immature will suffer relatively little consequence to disruption of breeding behavior when compared to an actively displaying adult of prime reproductive age.

Ultimate Life Functions

The ultimate life functions are those that enable an animal to contribute to the population (or stock, or species, etc.). The impact to ultimate life functions will depend on the nature and magnitude of the perturbation to proximate life history functions. Depending on the severity of the response to the stressor, acute perturbations may have nominal to profound impacts on ultimate life functions. For example, unit-level use of sonar by a vessel transiting through an area that is utilized for foraging, but not for breeding, may disrupt feeding by exposed animals for a brief period of time. Because of the brevity of the perturbation, the impact to ultimate life functions may be negligible. By contrast, weekly training over a period of years may have a more substantial impact because the stressor is chronic. Assessment of the magnitude of the stress response from the chronic perturbation would require an understanding of how and whether animals acclimate to a specific, repeated stressor and whether chronic elevations in the stress response (e.g., cortisol levels) produce fitness deficits.

The proximate life functions are loosely ordered in decreasing severity of impact. Mortality (survival) has an immediate impact, in that no future reproductive success is feasible and there is no further addition to the population resulting from reproduction. Severe injuries may also lead to reduced survivorship (longevity) and prolonged alterations in behavior. The latter may further affect an animal's overall reproductive success and reproductive effort. Disruptions of breeding have an immediate impact on reproductive effort and may impact reproductive success. The magnitude of the effect will depend on the duration of the disruption and the type of behavior change that was provoked. Disruptions to feeding and migration can affect all of the ultimate life functions; however, the impacts to reproductive effort and success are not likely to be as severe or immediate as those incurred by mortality and breeding disruptions.

Application of the Framework

For each species in the region of a proposed action, the density and occurrence of the species in the region relative to the timing of the proposed action should be determined. The probability of exposing an individual will be based on the density of the animals at the time of the action and the acoustic propagation loss. Based upon the calculated exposure levels for the individuals, or proportions of the population, an assessment for auditory and nonauditory responses should be made. Based on the available literature on the bioacoustics, physiology, dive behavior, and ecology of the species, Figure 6-7 should be used to assess the potential impact of the exposure to the population and species.

Regulatory Framework

The MMPA prohibits the unauthorized harassment of marine mammals and provides the regulatory processes for authorization for any such harassment that might occur incidental to an otherwise lawful activity.

The regulatory framework for estimating potential acoustic effects from NSWC PCD RDT&E activities on marine mammal species makes use of the methodology that was developed in cooperation with National Oceanic and Atmospheric Administration (NOAA) for the Navy's Draft *Overseas Environmental Impact Statement/Environmental Impact Statement, Undersea Warfare Training Range (OEIS/EIS)* (DON, 2005). Via response comment letter to USWTR received from NMFS January 30, 2006, NMFS concurred with the use of EL for the determination of physiological effects to marine mammals. Therefore, this methodology was used to estimate the annual exposure of marine mammals that may be considered Level A harassment (sound level threshold of 215 dB or above) or Level B harassment (sound levels below 215 dB down to 195 dB) as a result of temporary, recoverable physiological effects.

In addition, the approach for estimating potential acoustic effects from NSWC PCD RDT&E activities on cetacean species uses the methodology that the DON developed in cooperation with NOAA for the Navy's USWTR Draft OEIS/EIS (2005), Undersea Warfare Exercise (USWEX) EA/OEA (DON, 2005a, 2007b), RIMPAC EA/OEA (DON, Commander Third Fleet, 2006), Composite Training Unit Exercises (COMPTUEX)/ Joint Task Force Exercises (JTFEX) and COMPTUEX/JTFEX EA/OEA (DON, 2007c), and HRC Draft EIS (DON, 2007b). The exposure analysis for behavioral response to sound in the water uses energy flux density for Level A harassment and the methods for risk function for Level B harassment (behavioral). The methodology is provided here to determine the number and species of marine mammals for which incidental take authorization is requested.

A number of Navy actions and NMFS rulings have helped to qualify possible activities deemed as "harassment" under the MMPA. "Harassment" under the MMPA includes both potential injury (Level A) and disruptions of natural behavioral patterns to a point where they are abandoned or significantly altered (Level B). The acoustic effects analysis and exposure calculations are based on the following premises:

- Harassment that may result from Navy operations described in the NSWC PCD EIS/OEIS is unintentional and incidental to those operations.
- This LOA uses an unambiguous definition of injury as defined in the Undersea Warfare Training Range Draft OEIS/DEIS (DON, 2005) and in previous rulings (NOAA, 2001, 2002a): injury occurs when any biological tissue is damaged or lost as a result of the action.
- Behavioral disruption might result in subsequent injury and injury may cause a subsequent behavioral disruption, so Level A and Level B harassment categories (defined below in Section 4.7.3.1) can overlap and are not necessarily mutually exclusive. However, based on prior ruling (NOAA, 2001, 2006c), this LOA assumes that Level A and B do not overlap.
- An individual animal predicted to experience simultaneous multiple injuries, multiple disruptions, or both is counted as a single take (see NOAA, 2001, 2006c). An animal whose behavior is disrupted by an injury has already been counted as a Level A harassment and will not also be counted as a Level B harassment.
- The acoustic effects analysis is based on primary exposures to the action. Secondary or indirect effects, such as susceptibility to predation following injury and injury resulting from disrupted behavior may not be readily determined unless directly observed, or the risk of occurrence concluded from previous well-documented examples. Consideration of secondary effects would result in some Level A harassment being considered Level B harassment, and vice versa, since much injury (Level A harassment) has the potential to disrupt behavior (Level B harassment), and much temporary physiological or behavioral

disruption (Level B) could be conjectured to have the potential for injury (Level A). Consideration of secondary effects would lead to circular definitions of harassment.

- Animals are uniformly distributed and remain stationary during the active sonar events; therefore, the model does not account for any animal response.

Integration of Regulatory and Biological Frameworks

This section presents a biological framework within which potential effects can be categorized and then related to the existing regulatory framework of injury (Level A) and behavioral disruption (Level B). The information presented in the subsections below was used to develop specific numerical exposure thresholds and risk function estimations. Exposure thresholds were combined with sound propagation models and species distribution data to estimate the potential exposures.

Physiological and Behavioral Effects

Sound exposure may affect multiple biological traits of a marine animal; however, the MMPA as amended directs which traits should be used when determining effects. Effects that address injury are considered Level A harassment under MMPA. Effects that address behavioral disruption are considered Level B harassment under MMPA.

The biological framework discussed here is structured according to potential physiological and behavioral effects resulting from sound exposure. The range of effects may then be assessed to determine which qualify as injury or behavioral disturbance under MMPA regulations. Physiology and behavior are chosen over other biological traits because:

- They are consistent with regulatory statements defining harassment by injury and harassment by disturbance.
- They are components of other biological traits that may be relevant.
- They are a more sensitive and immediate indicator of effect.

For example, ecology is not used as the basis of the framework because the ecology of an animal is dependent on the interaction of an animal with the environment. The animal's interaction with the environment is driven both by its physiological function and its behavior, and an ecological effect may not be observable over short periods of observation. Ecological information is considered in the analysis of the effects to individual species.

A "physiological effect" is defined here as one in which the "normal" physiological function of the animal is altered in response to sound exposure. Physiological function is any of a collection of processes ranging from biochemical reactions to mechanical interaction and operation of organs and tissues within an animal. Physiological effects may range from the most significant of effects (i.e., mortality and serious injury) to lesser effects that define the lower end of the physiological effects range, such as the noninjurious distortion of auditory tissues. This latter physiological effect is important to the integration of the biological and regulatory frameworks and receives additional attention in later sections.

A “behavioral effect” is one in which the “normal” behavior or patterns of behavior of an animal are overtly disrupted in response to an acoustic exposure. Examples of behaviors of concern can be derived from the harassment definitions in the MMPA and the ESA.

In this LOA, the term “normal” is used to qualify distinctions between physiological and behavioral effects. Its use follows the convention of normal daily variation in physiological and behavioral function without the influence of anthropogenic (e.g., man-made) acoustic sources. As a result, this NSWC PCD LOA request uses the following definitions.

- A physiological effect is a variation in an animal’s physiology that results from an anthropogenic acoustic exposure and exceeds the normal daily variation in physiological function.
- A behavioral effect is a variation in an animal’s behavior or behavior patterns that results from an anthropogenic acoustic exposure and exceeds the normal daily variation in behavior but arises through normal physiological process.
- The definitions of physiological effect and behavioral effect used here are specific to this document and should not be confused with more global definitions applied to the field of biology.

It is reasonable to expect some physiological effects to result in subsequent behavioral effects. For example, a marine mammal that suffers a severe injury may be expected to alter diving or foraging to the degree that its variation in these behaviors is outside that which is considered normal for the species. If a physiological effect is accompanied by a behavioral effect, the overall effect is characterized as a physiological effect; physiological effects take precedence over behavioral effects with regard to their ordering. This approach provides the most conservative ordering of effects with respect to severity, provides a rational approach to dealing with the overlap of the definitions, and avoids circular arguments.

The severity of physiological effects generally decreases with decreasing sound exposure and/or increasing distance from the sound source. The same generalization does not consistently hold for behavioral effects because they do not depend solely on the received sound level. Behavioral responses also depend on an animal’s learned responses, innate response tendencies, motivational state, the pattern of the sound exposure, and the context in which the sound is presented. However, to provide a tractable approach to predicting acoustic effects that is relevant to the terms of behavioral disruption described in the MMPA, it is assumed here that the severities of behavioral effects also decrease with decreasing sound exposure and/or increasing distance from the sound source. Figure 6-8 shows the relationship between severity of effects, source distance, and exposure level, as defined in this LOA.

6.2.2 Calculation Methods

Detailed information and formulas to model the effects of sonar from RDT&E activities in the NSWC PCD Study Area is provided in Appendix A, Supplemental Information for Underwater Noise Analysis. The following section provides an overview of the methods used to conduct the analysis.

The quantitative analysis was based on conducting sonar operations in 16 different geographical regions, or provinces. Using combined marine mammal density and depth estimates, which is detailed later in this section, acoustical modeling was conducted to calculate the actual exposures. Refer to Appendix B, Geographic Description of Environmental Provinces, for additional information on provinces. Refer to Appendix C, Definitions and Metrics for Acoustic Quantities, for additional information regarding the acoustical analysis.

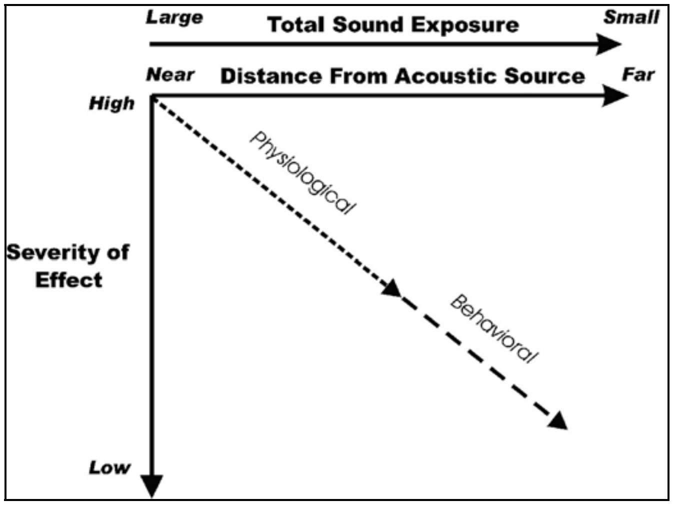


Figure 6-8. Relationship Between Severity of Effects, Source Distance, and Exposure Level

The approach for estimating potential acoustic effects from NSWC PCD RDT&E activities on cetacean species uses the methodology that the DON developed in cooperation with NOAA for the Navy's USWTR Draft OEIS/EIS (2005), Undersea Warfare Exercise (USWEX) Environmental Assessment (EA)/Overseas Environmental Assessment (OEA) (U.S. DON, 45, 2007a), RIMPAC EA/ OEA (DON, Commander Third Fleet, 2006), Composite Training Unit Exercises (COMPTUEX)/Joint Task Force Exercises (JTFEX) EA/OEA (DON, 2007b), and HRC Draft EIS (DON, 2007c). The exposure analysis for behavioral response to sound in the water uses energy flux density for Level A harassment and the methods for risk function for Level B harassment (behavioral). The methodology is provided here to determine the number and species of marine mammals for which incidental take authorization is requested.

To estimate acoustic effects from the NSWC PCD RDT&E activities, acoustic sources to be used were examined with regard to their operational characteristics as described in the previous section. In addition, systems with an operating frequency greater than 200 kHz were not analyzed in the detailed modeling as these signals attenuate rapidly resulting in very short propagation distances. Acoustic countermeasures were previously examined and found not to be problematic. These acoustic sources, therefore, did not require further examination in this analysis. Based on the information above, the Navy modeled the following systems:

- Kingfisher
- Sub-bottom profilers
- SAS-LFs and SAS-HFs
- Modems
- AN/SQQ-32

- BPAUVs
- ACL
- TVSS
- F84Y
- AN/AQS-20
- Navigation systems

Sonar parameters including source levels, ping length, the interval between pings, output frequencies, directivity (or angle), and other characteristics were based on records from on previous test scenarios and projected future testing. Additional information on sonar systems and their associated parameters is in Appendix A, Supplemental Information for Underwater Noise Analysis.

Every active sonar operation includes the potential to expose marine animals in the neighboring waters. The number of animals exposed to the sonar in any such action is dictated by the propagation field and the manner in which the sonar is operated (i.e., source level, depth, frequency, pulse length, directivity, platform speed, repetition rate). The modeling for NSWC PCD RDT&E activities involving sonar occurred in five broad steps, listed below and was conducted based on the typical RDT&E activities planned for the NSWC PCD Study Area.

Step 1. Environmental Provinces. The NSWC PCD Study Area is divided into 16 environmental provinces, and each has a unique combination of environmental conditions. These represent various combinations of eight bathymetry provinces, one Sound Velocity Profile (SVP) province, and three Low-Frequency Bottom Loss geo-acoustic provinces and two High-Frequency Bottom Loss classes. These are addressed by defining eight fundamental environments in two seasons that span the variety of depths, bottom types, sound speed profiles, and sediment thicknesses found in the NSWC PCD Study Area. The two seasons encompass winter and summer, which are the two extremes and for the GOM, the acoustic propagation characteristics do not vary significantly between the two. Each marine modeling area can be quantitatively described as a unique combination of these environments.

Step 2. Transmission Loss. Since sound propagates differently in these environments, separate transmission loss calculations must be made for each, in both seasons. The transmission loss is predicted using Comprehensive Acoustic Simulation System/Gaussian Ray Bundle (CASS-GRAB) sound modeling software.

Step 3. Exposure Volumes. The transmission loss, combined with the source characteristics, gives the energy field of a single ping. The energy of over 10 hours of pinging is summed, carefully accounting for overlap of several pings, so an accurate average exposure of an hour of pinging is calculated for each depth increment. At more than ten hours, the source is too far away and the energy is negligible. In addition, the acoustic modeling takes into account the use of a single system. Only one source will operate at any one time during NSWC PCD RDT&E activities.

Repeating this calculation for each environment in each season gives the hourly ensonified volume, by depth, for each environment and season. This step begins the method for risk function modeling.

Step 4. Marine Mammal Densities. The marine mammal densities were given in two dimensions, but using reliable peer-reviewed literature sources (published literature and agency reports) described in the following subsection, the depth regimes of these marine mammals are used to project the two dimensional densities (expressed as the number of animals per area where all individuals are assumed to be at the water's surface) into three dimensions (a volumetric approach whereby two-dimensional animal density incorporates depth into the calculation estimates).

Step 5. Exposure Calculations. Each marine mammal's three-dimensional (3-D) density is multiplied by the calculated impact volume to that marine mammal depth regime. This value is the number of exposures per hour for that particular marine mammal. In this way, each marine mammal's exposure count per hour is based on its density, depth habitat, and the ensonified volume by depth.

The planned sonar hours for each system were inserted and a cumulative number of exposures was determined for each alternative.

Marine Mammal Density

For the purposes of this analysis, NSWC PCD has adopted a conservative approach to underwater sound and marine mammals. Baleen and toothed whales, collectively known as cetaceans, spend their entire lives in the water and spend most of the time (greater than 90 percent for most species) entirely submerged below the surface. When at the surface, cetacean bodies are almost entirely below the water's surface, with only the blowhole exposed to allow breathing. This makes cetaceans difficult to locate visually and also exposes them to underwater sound, both natural and anthropogenic, essentially 100 percent of the time because their ears are nearly always below the water's surface. Therefore, the analysis assumes that the time cetaceans spend underwater and exposed to sound is 100 percent. The following subsection describes the density calculations and values used in this analysis.

There are several recent (from data collected in 1996–2001) density estimates available for most cetacean species, categorized into three depth regimes: 20–200 meters (m) (66–656 feet [ft]), 200–2,000 m (656–6,562 ft), and greater than 2,000 m (6,562 ft). The NSWC PCD Study Area overlies all three of these depth regimes to varying degrees. Planning for most operations within the NSWC PCD Study Area cannot be limited to specific depth zones. Therefore, cetacean densities per depth regime needed to be averaged to come up with a single density for each species in the NSWC PCD Study Area, which included the following steps:

1) Density (animals/square kilometers [km^2]) per species for each depth regime, taken from the published literature, was multiplied by the area of the depth regime to yield an abundance of animals.

2) The total number of animals per depth regime were then summed and divided by the total area of the NSWC PCD Study Area resulting in a density attributable to the entire region. The areas for each depth regime within the NSWC PCD Study Area, measured via ArcGIS, are:

   20–200 m (66–656 ft): 53,083 km^2 (20,496 square miles [mi^2])

   200–2,000 m (656–6,562 ft): 24,523 km^2 (9,496 mi^2)

   greater than 2,000 m (6,562 ft): 332 km^2 (124 mi^2)
   NSWC PCD Study Area: 77,938 km^2 (30,092 mi^2)

Table 6-1 presents densities from the published literature for several depth regimes. Only cetaceans for which densities are available are included in Table 6-2, which presents averaged densities from all depth regimes for the eastern Gulf of Mexico (GOM) region.

Table 6-1. Marine Mammal Densities for the NSWC PCD Study Area from Published Literature

Common Name	Scientific Name	Status	Occurrence Notes	Density/km² 20-200 m (66 – 656 ft) bathymetry line	Density/km² 200-2000 m (656 – 6,562 ft) bathymetry line	Density/km² >2000 m (>6,562 ft) bathymetry line	Season	Reference
MYSTICETES								
Blue whale	*Balaenoptera musculus*	Endangered	Extralimital					
Fin whale	*B. physalus*	Endangered	Rare					
Sei whale	*B. borealis*	Endangered	Extralimital					
Bryde's whale	*B. edeni*			0	0.0006	0	mid-April to early June	Mullin and Fulling (2004)
Minke whale	*B. acutorostrata*		Rare					
Humpback whale	*Megaptera novaeangliae*	Endangered	Extralimital					
North Atlantic right whale	*Eubalaena glacialis*	Endangered	Extralimital					
ODONTOCETES								
Sperm whale	*Physeter catodon*	Endangered		0	0.0015	0.0037	mid-April to early June	Mullin and Fulling (2004)
Kogia sp, including pygmy and dwarf sperm whales	*Kogia sp*			0	0.0015	0.0021	mid-April to early June	Mullin and Fulling (2004)
Cuvier's beaked whale	*Ziphius cavirostris*			0	0.0004	0.0001	mid-April to early June	Mullin and Fulling (2004)
Unidentified beaked whales	*Ziphiidae*			0	0	0.0007	mid-April to early June	Mullin and Fulling (2004)

Table 6-1. Marine Mammal Densities for the NSWC PCD Study Area from Published Literature Cont'd

Common Name	Scientific Name	Status	Occurrence Notes	Density/km^2 20-200 m (66 – 656 ft) bathymetry line	Density/km^2 200-2000 m (656 – 6,562 ft) bathymetry line	Density/km^2 >2000 m (>6,562 ft) bathymetry line	Season	Reference
Mesoplodonts, including Gervais', Sowerby's and Blainville's beaked whales	*Mesoplodon sp*			0	0.0003	0.0001	mid-April to early June	Mullin and Fulling (2004)
Killer whale	*Orcinus orca*			0	0	0.0005	mid-April to early June	Mullin and Fulling (2004)
False killer whale	*Pseudorca crassidens*			0	0.0053	0.0037	mid-April to early June	Mullin and Fulling (2004)
Pygmy killer whale	*Feresa attenuata*			0	0	0.0022	mid-April to early June	Mullin and Fulling (2004)
Short-finned pilot whale	*Globicephala macrorhynchus*			0	0	0	mid-April to early June	Mullin and Fulling (2004)
Melon-headed whale	*Peponocephala electra*			0	0	0	mid-April to early June	Mullin and Fulling (2004)
Risso's dolphin	*Grampus griseus*			0	0.0085	0.0043	mid-April to early June	Mullin and Fulling (2004)

Table 6-1. Marine Mammal Densities for the NSWC PCD Study Area from Published Literature Cont'd

Common Name	Scientific Name	Status	Occurrence Notes	Density/km^2 20-200 m (66 – 656 ft) bathymetry line	Density/km^2 200-2000 m (656 – 6,562 ft) bathymetry line	Density/km^2 >2000 m (>6,562 ft) bathymetry line	Season	Reference
Rough-toothed dolphin	*Steno bredanensis*			0.004	0.0024	0.0014	late Aug-early Oct for 20-200 m surveys; mid-April to early June for deeper surveys	Fulling et al. (2003); Mullin and Fulling (2004)
Bottlenose dolphin	*Tursiops truncatus*			0.109	0.0294	0	late Aug-early Oct for 20-200 m surveys; mid-April to early June for deeper surveys	Fulling et al. (2003); Mullin and Fulling (2004)
Atlantic spotted dolphin	*Stenella frontalis*			0.201	0	0	late Aug-early Oct for 20-200 m surveys; mid-April to early June for deeper surveys	Fulling et al. (2003); Mullin and Fulling (2004)

Table 6-1. Marine Mammal Densities for the NSWC PCD Study Area from Published Literature Cont'd

Common Name	Scientific Name	Status	Occurrence Notes	Density/km² 20-200 m (66 – 656 ft) bathymetry line	Density/km² 200-2000 m (656 – 6,562 ft) bathymetry line	Density/km² >2000 m (>6,562 ft) bathymetry line	Season	Reference
Combined bottlenose and Atlantic spotted dolphins				0.007			late Aug-early Oct	Fulling et al. (2003)
Striped dolphin	*Stenella coeruleoalba*			0	0.0082	0.0147	mid-April to early June	Mullin and Fulling (2004)
Pantropical spotted dolphin	*Stenella attenuata*			0	0.2482	0.2983	mid-April to early June	Mullin and Fulling (2004)
Spinner dolphin	*Stenella longirostris*			0	0.173	0.0042	mid-April to early June	Mullin and Fulling (2004)
Clymene dolphin	*Stenella clymene*			0	0	0.0583	mid-April to early June	Mullin and Fulling (2004)
Unidentified *Stenella*	*Stenella sp*			0	0.0012	0.0019	mid-April to early June	Mullin and Fulling (2004)
Fraser's dolphin	*Lagenodelphis hosei*			0	0.0112	0	mid-April to early June	Mullin and Fulling (2004)
SIRENIANS								
West Indian Manatee	*Trichechus manatus*	Endangered	Extralimital					

Table 6-2. Marine Mammal Densities Averaged for Eastern GOM

Common Name	Density/km^2 20-200 m (66-656 ft)	# whales 20-200 m (66 – 656 ft) (area=53,083 km^2 [20,495 mi^2])	Density/km^2 200-2000 m (656 – 6,562 ft) bathymetry line	#whales 200-2000 m (656 – 6,562 ft) (area=24,523 km^2 [9,495 mi^2]) bathymetry line	Density/km^2 >2000 m (> 6,562 ft) bathymetry line	#whales >2000 m (6,562 ft) (area=332 km^2 [124 mi^2]) bathymetry line	Total whales for eastern GOM	Density/km^2 eastern GOM (area=77,938 km^2 [30,092 mi^2])
MYSTICETES								
Bryde's whale	0		0.0006	15	0		15	0.0002
ODONTOCETES								
Sperm whale	0		0.0015	37	0.0037	1	38	0.0005
Kogia sp, including pygmy and dwarf sperm whales	0		0.0015	37	0.0021	1	37	0.0005
Cuvier's beaked whale	0		0.0004	10	0.0001	0	10	0.0001
Unidentified beaked whales	0		0		0.0007	0	0	0.000003
Mesolplodonts, including Gervais', Sowerby's and Blainville's beaked whales	0		0.0003	7	0.0001	0	7	0.0001
Killer whale	0		0		0.0005	0	0	0.000002
False killer whale	0		0.0053	130	0.0037	1	131	0.0017
Pygmy killer whale	0		0		0.0022	1	1	0.000009
Short-finned pilot whale	0		0		0		0	0.0000
Melon-headed whale	0		0		0		0	0.0000
Risso's dolphin	0		0.0085	208	0.0043	1	210	0.0027
Rough-toothed dolphin	0.004	212	0.0024	59	0.0014	0	272	0.0035

Table 6-2. Marine Mammal Densities Averaged for Eastern GOM Cont'd

Common Name	Density/km^2 20-200 m (66-656 ft)	# whales 20-200 m (66 – 656 ft) (area=53,083 km^2 [20,495 mi^2])	Density/km^2 200-2000 m (656 – 6,562 ft) bathymetry line	#whales 200-2000 m (656 – 6,562 ft) (area=24,523 km^2 [9,495 mi^2]) bathymetry line	Density/km^2 >2000 m (> 6,562 ft) bathymetry line	#whales >2000 m (6,562 ft) (area=332 km^2 [124 mi^2]) bathymetry line	Total whales for eastern GOM	Density/km^2 eastern GOM (area=77,938 km^2 [30,092 mi^2])
Bottlenose dolphin	0.109	5786	0.0294	721	0		6507	0.0835
Atlantic spotted dolphin	0.201	10670	0		0		10670	0.1369
Bottlenose + Atlantic spotted	0.007	372					372	0.0048
Striped dolphin	0		0.0082	201	0.0147	5	206	0.0026
Pantropical spotted dolphin	0		0.2482	6087	0.2983	99	6186	0.0794
Spinner dolphin	0		0.173	4242	0.0042	1	4244	0.0545
Clymene dolphin	0		0		0.0583	19	19	0.0002
Unidentified *Stenella*	0		0.0012	29	0.0019	1	30	0.0004
Fraser's dolphin	0		0.0112	275	0		275	0.0035

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys
**Unidentified *Stenella* includes pantropical spotted, striped, spinner, and clymene dolphins that were not differentiated during scientific surveys

Depth Distribution

There are limited depth distribution data for most marine mammals. This is especially true for cetaceans, as they must be tagged at-sea by using a tag that either must be implanted in the skin/blubber in some manner or adhere to the skin. There are a few different methodologies/techniques that can be used to determine depth distribution percentages, but by far the most widely used technique currently is the time-depth recorder. These instruments are attached to the animal for a fairly short period of time (several hours to a few days) via a suction cup or glue, and then retrieved immediately after detachment. Depth information can also be collected via satellite tags, sonic tags, digital tags, and, for sperm and beaked whales, via acoustic tracking of sounds produced by the animal itself. Additional information on depth distribution for marine mammals in the NSWC PCD Study Area is included in Appendix A, specifically in Table A-8.

There are suitable depth distribution data for some marine mammal species. Sample sizes are usually extremely small, almost always encompassing fewer than 10 animals total and usually include only one or two animals. Depth distribution information can also be interpreted from other dive and/or preferred prey characteristics, and from methods including behavioral observations, stomach content analysis and habitat preference analysis. Depth distributions for species for which no data are available are extrapolated from similar species.

Density and Depth Distribution Combined

Density is nearly always reported for an area (e.g., animals/km^2). Analyses of survey results using distance sampling techniques include correction factors for animals at the surface but not seen and for animals below the surface but not observed. Therefore, although the area (e.g., km^2) appears to represent only the surface of the water (two-dimensional), density actually implicitly includes animals anywhere within the water column under that surface area. Density assumes that animals are uniformly distributed within the prescribed area, although this assumption is likely rare. Marine mammals are usually clumped in areas of greater importance, for example, in areas of high productivity, lower predation, and safe calving. Density can be calculated occasionally for smaller areas that are used regularly by marine mammals; however, oftentimes there are insufficient data to calculate density for small areas. Therefore, assuming an even distribution within the prescribed area remains the standard method.

Assuming that marine mammals are distributed evenly within the water column does not accurately reflect marine mammal behavior. The ever-expanding database of marine mammal behavioral and physiological parameters obtained through tagging and other technologies has demonstrated that marine mammals use the water column in various ways. Some species are capable of regular deep dives greater than 800 m (2,625 ft) and others dive to less than 200 m (656 ft), regardless of the bottom depth. Assuming that all species are evenly distributed from the surface to the bottom is almost never appropriate and can present a distorted view of marine mammal distribution in any region.

By combining marine mammal density with depth distribution information, a 3-D density estimate is possible. These 3-D estimates allow more accurate modeling of potential marine mammal exposures from specific sonar systems.

Other Potential Acoustic Effects to Marine Mammals

Acoustically Mediated Bubble Growth

One suggested cause of injury to marine mammals is rectified diffusion, which is the process of increasing the size of a bubble by exposing it to a sound field (Crum and Mao, 1996). This process is facilitated if the environment in which the ensonified bubbles exist is supersaturated with a gas, such as nitrogen, which makes up approximately 78 percent of air. Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard, 1979). Deeper and longer dives of some marine mammals (e.g., beaked whales) are theoretically predicted to induce greater supersaturation (Houser et al., 2001). Conversely, studies have shown that marine mammal lung structure (both pinnipeds and cetaceans) facilitates collapse of the lungs at depths below approximately 50 m (162 ft) (Kooyman et al., 1970). Collapse of the lungs would force air into the nonair exchanging areas of the lungs (into the bronchioles away from the alveoli) thus significantly decreasing nitrogen diffusion into the body. Deep-diving pinnipeds such as the northern elephant (*Mirounga angustirostris*) and Weddell seals (*Leptonychotes weddellii*) typically exhale before long deep dives, further reducing air volume in the lungs (Kooyman et al., 1970). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness.

It is unlikely that the short duration of sonar pings will be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested: stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario, the marine mammal would need to be in a gas-supersaturated state for a long enough period of time for bubbles to become of a problematic size.

Another hypothesis suggests that rapid ascent to the surface following exposure to a startling sound might produce tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson et al., 2003). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation. Cox et al. (2006), with experts in the field of marine mammal behavior, diving, physiology, respiration physiology, pathology, anatomy, and bio-acoustics considered this to be a plausible hypothesis that requires further investigation. Conversely Fahlman et al. (2006) suggested by formulation of a mathematical model that diving bradycardia (reduction in heart rate and circulation to the tissues), lung collapse, and slow ascent rates would reduce nitrogen uptake and thus reduce the risk of decompression sickness by 50 percent in models of marine mammals. Recent information on the diving profiles of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales (Baird et al., 2006) in the Ligurian Sea in Italy (Tyack et al., 2006) showed that while these species do dive deeply (regularly exceed depths of 800 m [.5 mi]) and for long periods (48–68 minutes), they have significantly slower ascent rates than descent rates. This fits well with Fahlman et al., (2006) model of deep and long duration divers that would have slower ascent rates to reduce nitrogen saturation and reduce the risk of decompression sickness. Therefore, if nitrogen saturation remains low, then a rapid ascent should not cause decompression sickness. Currently, it is not known if beaked whales rapidly ascend in response to sonar or other disturbances. Deep diving animals may be better protected by diving to depth to avoid predators, such as killer whales, rather then ascending to the surface where they may be more susceptible to predators, subsequently eliminating a rapid ascent.

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann, 2004; Evans and Miller, 2004). To date, ELs predicted to cause *in vivo* bubble formation within diving cetaceans have not been evaluated (NOAA, 2002b). Further, although it has been argued that traumas from recent beaked whale strandings are consistent with gas emboli- and bubble-induced tissue separations (Jepson et al., 2003), there is no conclusive evidence of this occurrence. In addition, there may be complicating factors associated with introduction of gas into the venous system during necropsy. Because evidence supporting it is debatable, no marine mammals addressed in this LOA are given special treatment due to the possibility for acoustically mediated bubble growth.

Resonance

Another suggested cause of injury in marine mammals is air cavity resonance due to sonar exposure. Resonance is a phenomenon that exists when an object is vibrated at a frequency near its natural frequency of vibration, or the particular frequency at which the object vibrates most readily. The size and geometry of an air cavity determine the frequency at which the cavity will resonate. Displacement of the cavity boundaries during resonance has been suggested as a cause of injury. Large displacements have the potential to tear tissues that surround the air space (e.g., lung tissue).

Understanding resonant frequencies and the susceptibility of marine mammal air cavities to resonance is important in determining whether certain sonars have the potential to affect different cavities in different species. In 2002, NMFS convened a panel of government and private scientists to address this issue (NOAA, 2002b). They modeled and evaluated the likelihood that U.S. Navy MFA sonar caused resonance effects in beaked whales that eventually led to their stranding (Department of Commerce [DOC] and DON, 2001). The conclusions of that group were that frequencies predicted to cause resonance in air-filled structures were below the frequencies produced by the sonar systems in use. Furthermore, air cavity vibrations due to the resonance effect were not considered to be of sufficient amplitude to cause tissue damage. The NSWC PCD EIS/OEIS and this LOA request assumes that similar phenomenon will not be problematic in other cetacean species.

Prolonged Exposure

NSWC PCD RDT&E activities will not result in prolonged exposure because of the intermittent nature of sonar transmissions and the generally short duration of tests. The implementation of the protective measures discussed in Chapter 11 will further reduce the likelihood of any prolonged exposure.

Masking

Natural and artificial sounds can disrupt behavior by masking, or interfering with an animal's ability to hear other sounds. Masking occurs when the receipt of a sound is interfered with by a second sound at similar frequencies and at similar or higher levels. If the second sound were artificial, it could be potentially harassing if it disrupted hearing-related behavior such as communications or echolocation. It is important to distinguish TTS and PTS, which persist after the sound exposure, from masking, which occurs during the sound exposure.

Historically, principal masking concerns have been with prevailing background sound levels from natural and man-made sources (e.g., Richardson et al., 1995). Dominant examples of the latter are the accumulated sound from merchant ships and sound of seismic surveys. Both cover a wide frequency band and are long in duration.

The majority of proposed NSWC PCD RDT&E activities is away from harbors or heavily traveled shipping lanes. The sonar signals are likely within the audible range of most cetaceans, but are very limited in the temporal and frequency domains. In particular, the pulse lengths are short, the duty cycle low, and these active sonars transmit within a narrow band of frequencies (typically less than one-third octave). For the reasons outlined above, the chance of sonar operations causing masking effects is considered negligible.

6.2.3 Marine Mammal Exposures

Sonar operations in territorial waters may expose bottlenose dolphins and Atlantic spotted dolphins to sound likely to result in Level B (behavioral) harassment. In addition, one bottlenose dolphin and two Atlantic spotted dolphins may be exposed to levels of sound likely to result in TTS (Table 6-3).

Table 6-3. Estimates of Marine Mammal Exposures from Sonar Missions in Territorial Waters Per Year

Marine Mammal Species	Level A	Level B (TTS)	Level B (Behavioral)
Bottlenose dolphin	0	1	72
Atlantic spotted dolphin	0	2	362
Combined bottlenose and Atlantic spotted dolphin*	0	0	26

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys

Sonar operations in non-territorial waters may expose up to twelve species to sound likely to result in Level B (behavioral) harassment (Table 6-4). They include the Bryde's whale, sperm whale, false killer whale, Risso's dolphin, rough-toothed dolphin, bottlenose dolphin, Atlantic bottlenose dolphin, Atlantic spotted dolphin, pantropical spotted dolphin, striped dolphin, spinner dolphin, Clymene dolphin, and Fraser's dolphin. In addition, sonar operations in non-territorial waters may expose up to one bottlenose dolphin, Atlantic spotted dolphin, and pantropical spotted dolphin to levels of sound likely to result in TTS. The only potential impacts to marine mammals will occur at Level B harassment.

Table 6-4. Estimates of Marine Mammal Exposures from Sonar Missions in Non-territorial Waters Per Year

Marine Mammal Species	Level A	Level B (TTS)	Level B (Behavioral)
Bryde's whale	0	0	1
Sperm whale	0	0	2
Dwarf/Pygmy sperm whale	0	0	0
All beaked whales	0	0	0
Killer whale	0	0	0
False killer whale	0	0	6
Pygmy killer whale	0	0	0
Risso's dolphin	0	0	10
Rough-toothed dolphin	0	0	12
Bottlenose dolphin	0	1	26
Atlantic spotted dolphin	0	1	108
Combined bottlenose and Atlantic spotted dolphins*	0	0	6
Pantropical spotted dolphin	0	1	257
Striped dolphin	0	0	7
Spinner dolphin	0	0	181
Clymene dolphin	0	0	1
Unidentified *Stenella***	0	0	1
Fraser's dolphin	0	0	14

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys
**Unidentified *Stenella* includes pantropical spotted, striped, spinner, and Clymene dolphins that were not differentiated during scientific surveys

Potential for Long-Term Effects

NSWC PCD RDT&E activities will be conducted in the same general areas, so marine mammal populations could be exposed to repeated activities over time. However, as described earlier, this LOA assumes that short-term noninjurious SELs predicted to cause TTS or temporary behavioral disruptions qualify as Level B harassment. It is highly unlikely that all behavioral disruptions or instances of TTS will result in long-term significant effects.

6.2.4 Summary of Potential Acoustic Effects from Sonar by Marine Mammal Species

Acoustical modeling provides an estimate of the actual exposures. As previously mentioned, NSWC PCD RDT&E activities involve mid-frequency sonar operation for only 10 percent of operational hours. Furthermore, testing generally involves short-term use and single systems at once.

Territorial Waters

The bottlenose and Atlantic spotted dolphin are the only marine mammals that would occur in territorial waters. Sonar analysis indicates that zero bottlenose and Atlantic spotted dolphins will be exposed to levels of sound likely to result in Level A harassment, therefore the following subsections will discuss the potential effects to these species from sonar exposure associated with NSWC PCD RDT&E activities at sound levels likely to result only in Level B (TTS) and Level B (behavioral) harassment.

Bottlenose Dolphin

The best estimate of abundance along the GOM continental shelf and slope is 25,320, with a minimum population estimate of 20,414 bottlenose dolphins (Waring et al., 2007). Sonar analysis indicated that only one bottlenose dolphin will be exposed to levels of sound likely to result in Level B (TTS) harassment. The risk function and Navy post-modeling analysis estimates that 98 bottlenose dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data, 0.32 percent of the northern GOM stock of bottlenose dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to bottlenose dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to bottlenose dolphins.

Atlantic Spotted Dolphin

The best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins (Waring et al., 2007). Sonar analysis indicated that two Atlantic spotted dolphin will be exposed to levels of sound likely to result in Level B (TTS) harassment. Based on the exposure data and the best estimate of abundance, 0.0065 percent of the northern GOM stock of Atlantic spotted dolphins will be exposed to levels of sound likely to result in Level B (TTS) harassment. The risk function and Navy post-modeling analysis estimates that 388 Atlantic spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data, 1.25 percent of the northern GOM stock of Atlantic spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA . The assumption is conservatively made to count the six combined bottlenose and Atlantic spotted dolphin for each group. These exposures will not necessarily occur to different individuals as the same species could be exposed multiple times over the duration of the sonar tests. Thus, the estimated number of Atlantic spotted dolphins experiencing harassment may be fewer than previously stated.

Based on the best available science, the Navy concludes that exposures to Atlantic spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Atlantic spotted dolphins.

Non-Territorial Waters

The following subsections present the summary for species with potential to be exposed to sound based on the previous sonar analysis. The results of this analysis indicate that no marine mammal species will be exposed to levels of sound likely to result in Level A harassment. Additionally, only three marine mammal species (bottlenose dolphin, Atlantic spotted dolphin, and pantropical spotted dolphin) are expected to result in Level B (TTS) harassment. The subsections discussing those species will include those effects. The other subsections will only present information for the marine mammal species with the potential to be exposed to sound levels resulting in Level B (behavioral) harassment.

Bryde's whale

The best abundance estimate for Bryde's whales in the GOM is 40, with a minimum population estimate of 25 (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that one Bryde's whale will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data and the best estimate of abundance, 2.5 percent of the northern GOM stock of Bryde's whales will exhibit behavioral responses that NMFS will classify as harassment. The Navy has initiated consultation with NMFS in accordance with the MMPA for concurrence.

Sperm Whale

In the GOM, the best abundance estimate for sperm whales is 1,349, with a minimum population estimate of 1,114 (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that two sperm whales will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data and the best estimate of abundance, 0.15 percent of the northern GOM stock of sperm whales will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to sperm whales due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to sperm whales.

False Killer Whale

The best estimate of abundance for false killer whales in the northern GOM is 1,038. The minimum population estimate is 606 false killer whales (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that six false killer whales will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data and the best estimate of abundance, 0.58 percent of the northern GOM stock of false killer whales will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to false killer whales due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to false killer whales.

Risso's Dolphin

The best estimate of abundance for Risso's dolphins in the northern GOM is 2,169, with a minimum population estimate of 1,668 Risso's dolphins (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that three Risso's dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA Based on this exposure data and the best estimate of abundance, 0.14 percent of the northern GOM stock of Risso's dolphin will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to Risso's dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Risso's dolphins.

Rough-Toothed Dolphin

The best estimate of abundance for rough-toothed dolphins is 2,223 in the northern GOM. The minimum population estimate for the same area is 1,595 rough-toothed dolphins (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that twelve rough-toothed dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on this exposure data and the best estimate of abundance, 0.54 percent of the northern GOM stock of rough-toothed dolphin will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to rough-toothed dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to rough-toothed dolphins.

Bottlenose Dolphin

As previously mentioned, the best estimate of abundance for bottlenose dolphins along the GOM continental shelf and slope is 25,320, with a minimum population estimate of 20,414 bottlenose dolphins (Waring et al., 2007). This was one of the marine mammal species that may experience levels of sound likely to result in Level B (TTS) and Level B (behavioral) harassments. Sonar analysis indicated that one bottlenose dolphin will be exposed to levels of sound likely to result in Level B (TTS) harassment. Based on exposure data and the best estimate of abundance, 0.0039 percent of the northern GOM continental shelf and slope bottlenose dolphins will be exposed to levels of sound likely to result in Level B (TTS) harassment. The risk function and Navy post-modeling analysis estimates that 26 bottlenose dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA under the No Action. Based on the exposure data, 0.10 percent of the northern GOM stock of bottlenose dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to bottlenose dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to bottlenose dolphins.

Atlantic Spotted Dolphin

As previously mentioned, the best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins (Waring et al., 2007). This was also one of the marine mammal species that may experience levels of sound likely to result in Level B (TTS) and Level B (behavioral) harassments. Sonar analysis indicated that one Atlantic spotted dolphin will be exposed to levels of sound likely to result in Level B (TTS) harassment. Based on exposure data and the best estimate of abundance, 0.0032 percent of the northern GOM Atlantic spotted dolphins will be exposed to levels of sound likely to result in Level B (TTS) harassment. The risk function and Navy post-modeling analysis estimates that 108 Atlantic spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data, 0.35 percent of the northern GOM stock of Atlantic spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to Atlantic spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Atlantic spotted dolphins.

Pantropical Spotted Dolphin

The best estimate of abundance for pantropical spotted dolphins in the northern GOM is 91,321, with a minimum population of 79,879 dolphins (Waring et al., 2007). This is the final marine mammal species that may experience levels of sound likely to result in Level B (TTS) and Level B (behavioral) harassments. Sonar analysis indicated that one pantropical spotted dolphin will be exposed to levels of sound likely to result in Level B (TTS) harassment. Based on exposure data and the best estimate of abundance, 0.0011 percent of the northern GOM pantropical spotted dolphins will be exposed to levels of sound likely to result in Level B (TTS) harassment. The risk function and Navy post-modeling analysis estimates that 258 pantropical spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on the exposure data, 0.28 percent of the northern GOM stock of pantropical spotted dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to pantropical spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to pantropical spotted dolphins.

Striped Dolphin

The best abundance estimate for striped dolphins in the northern GOM is 6,505, with a minimum population estimate of 4,599 striped dolphins (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that eight striped dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on this exposure data and the best estimate of abundance, 0.046 percent of the northern GOM stock of striped dolphin will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to striped dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to striped dolphins.

Spinner Dolphin

The best estimate of abundance for spinner dolphins is 11,971. The minimum population estimate for the northern GOM is 6,990 spinner dolphins (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that 182 spinner dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on this exposure data and the best estimate of abundance, 1.52 percent of the northern GOM stock of spinner dolphin would potentially be exposed to levels of sound likely to result in Level B (behavioral) harassment.

Based on the best available science, the Navy concludes that exposures to spinner dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to spinner dolphins.

Clymene dolphin

The best estimate of abundance for Clymene dolphins in the northern GOM is 17,355, with a minimum population estimate of 10,528 animals (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that two Clymene dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on this exposure data and the best estimate of abundance, 0.011 percent of the northern GOM stock of Clymene dolphin will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to Clymene dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Clymene dolphins.

Fraser’s Dolphin

The best estimate of abundance for Fraser’s dolphins in the northern GOM is 726, with a minimum population estimate of 427 animals (Waring et al., 2007). The risk function and Navy post-modeling analysis estimates that 14 Fraser’s dolphins will exhibit behavioral responses that NMFS will classify as harassment under the MMPA. Based on this exposure data and the best estimate of abundance, 1.93 percent of the northern GOM stock of Fraser’s dolphin will exhibit behavioral responses that NMFS will classify as harassment under the MMPA.

Based on the best available science, the Navy concludes that exposures to Fraser's dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Fraser's dolphins.

6.3 ACOUSTIC EFFECTS: ORDNANCE

Live ordnance testing may occur from the surf zone out to the outer perimeter of the NSWC PCD Study Area. The size and weight of the explosives used would vary from 0.91 to 272 kilogram (kg) (2 to 600 pound [lb]) trinitrotoluene (TNT) equivalent net explosive weight (NEW). No detonations over 34 kg (75 lb) NEW will be conducted within the territorial waters of the NSWC PCD Study Area. Operations involving live explosives include mine detonations and surf zone line charge detonations.

6.3.1 Introduction and Approach to Analysis

Underwater detonations may project pressure and sound intensities sufficient to cause physical trauma or acoustic or behavioral effects to protected marine mammals. Refer to the beginning of Section 6.1 for information related to MMPA Level A and Level B harassment.

Determining the potential exposures associated with ordnance operations is very similar to determining potential exposures associated with sonar operations. Refer to Appendix C, Definitions and Metrics for Acoustic Quantities, for additional information.

Metrics: Underwater Explosive Sound

Four standard acoustic metrics for measuring underwater pressure waves were used in this analysis:

- Total Energy Flux Density Level (EFD)
- 1/3-Octave EFD
- Positive Impulse
- Peak Pressure

Total EFD

Total EFD is the metric used for analyzing the level of sound that would cause a permanent decrease in hearing sensitivity. Decibels are used to express this metric.

1/3-Octave EFD

One-third octave EFD is the metric used in discussions of temporary (i.e., recoverable) hearing loss and for behavioral response thresholds of protected species to sound. One-third octave EFD is the energy flux density in the 1/3-octave frequency band at which the animal potentially exposed hears best. Decibels are also used to express this metric. This metric is used for analyzing underwater detonations.

Positive Impulse

Positive impulse is the metric used for analyzing lethal sound levels, as well as sound that marks the onset of slight lung injury in cetaceans. Positive impulse as it is used here is based on an equation modified by Goertner (1982); thus it is more completely stated as the Goertner-modified positive impulse. The units to express this metric are pounds per square inch per millisecond (psi-ms).

Peak Pressure

This is the maximum positive pressure for an arrival of a sound pressure wave that a marine mammal would receive at some distance away from a detonation. Units used here are pounds per square inch (psi) and dB levels.

Criteria and Thresholds for Explosive Sound

Criteria and thresholds for estimating the effects on protected species including marine mammals and sea turtles from a single explosive event were established and publicly vetted through the National Environmental Policy Act (NEPA) process during the Seawolf Submarine Shock Test Final Environmental Impact Statement (FEIS) ("Seawolf") and the USS Winston S. Churchill (DDG-81) Ship Shock FEIS ("Churchill") (DON, 2001). These criteria and thresholds were adopted by NMFS in its final rule on unintentional taking of marine animals incidental to the shock testing. The risk assessment approach for all gunfire-related sound in water was derived from the Seawolf/Churchill approach.

Criteria and Thresholds for Physiological Effects to Explosive Sound

The criterion for mortality for marine mammals used in the Churchill FEIS is "onset of severe lung injury." This criterion is conservative in that it corresponds to a 1 percent chance of mortal injury, and yet any animal experiencing onset severe lung injury is counted as a lethal exposure. The threshold is stated in terms of the Goertner (1982) modified positive impulse with value "indexed to 31 psi-msec." Since the Goertner approach depends on propagation, source/animal depths, and animal mass in a complex way, the actual impulse value corresponding to the 31 psi-msec index is a complicated calculation. Again, to be conservative, Churchill used the mass of a calf dolphin (at 12.2 kg or 26.9 pounds [lb]), so that the threshold index is 30.5 psi-msec.

For injury, two criteria are used: 50 percent eardrum rupture (i.e., tympanic membrane [TM] rupture) and onset of slight lung injury. These criteria are considered indicative of the onset of injury. The threshold for TM rupture corresponds to a 50 percent rate of rupture (i.e., 50 percent of animals exposed to the level are expected to suffer TM); this is stated in terms of an EL value of 1.17 inches per pound per square inch (in-lb/in^2) (about 205 dB re 1 μPa^2-s). This recognizes that TM rupture is not necessarily a serious or 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 PTS at the same threshold).

The threshold for onset of slight lung injury is calculated for a calf dolphin (12.2 kg [27 lb]); it is given in terms of the "Goertner modified positive impulse," indexed to 13 psi-ms. This is a departure from the Churchill and Seawolf approaches in the use of animal mass in the Goertner threshold for slight lung injury. In this assessment, cetaceans are assessed as calves, defined as those with mass less than 174 kg (384 lb). The associated threshold is indexed to 13 psi-msec, which corresponds to a calf dolphin at 12.2 kg (27 lb) (DON, 2001).

The first criterion for non-injurious harassment is TTS, which is defined as a temporary, recoverable loss of hearing sensitivity (NMFS, 2001; DON, 2001). The criterion for TTS is 182 dB re 1 μPa^2-s, which is the greatest energy flux density level in any 1/3-octave band at frequencies above 100 Hz for marine mammals.

The second criterion for estimating TTS threshold applies to all cetacean species and is stated in terms of peak pressure at 23 psi. The threshold is derived from the Churchill threshold which 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 in Churchill 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, 2006a). 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 shots while preserving the safety feature provided by the peak pressure threshold, the peak pressure 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 marine mammal TTS for explosives offers a safety margin for source or animal near the ocean surface.

Criteria and Thresholds for Behavioral Effects to Explosive Sound

For a single explosion, to be consistent with Churchill, TTS is the criterion for Level B harassment. In other words, because behavioral disturbance for a single explosion is likely to be limited to a short-lived startle reaction, use of the TTS criterion is considered sufficient protection. Behavioral modification (sub-TTS) is only applied to successive detonations. For single detonations, behavioral disturbance is likely to be limited to a short-lived startle reaction; therefore, use of the TTS criterion is considered sufficient protection.

Summary of Criteria and Thresholds for Explosive Sound

Table 6-5 summarizes the criteria and thresholds used in calculating the potential impacts to marine mammal from explosive sound.

6.3.2 Calculation Methods

An overview of the methods to determine the number of exposures of MMPA-protected species to sound likely to result in injury, mortality, Level A harassment, or Level B harassment is provided in the following paragraphs. Appendix A, Supplemental Information for Underwater Noise Analysis, includes specific formulas and more detailed information.

Acoustic threshold areas are derived from mathematical calculations and models that predict the distances or range to which threshold sound levels will travel. Sound is assumed to spread more or less spherically. Therefore, the range of influence is the radius of an ensonified area (the area exposed to sound). The equations for the models consider the amount of net explosive and the properties of detonations under water as well as environmental factors such as depth of the explosion, overall water depth, water temperature, and bottom type. Various combinations of these environmental factors result in a number of environmental provinces.

The result of the calculations and/or modeling is a volume. There are separate volumes for mortality, injury (hearing-related and slight lung), and harassment (TTS and behavioral). For mine detonations, the sound effects were modeled using the different net explosive weights at 16 environmental provinces during the winter and summer seasons. The three ranges of NEW for mine detonations mirror the ranges identified in the analysis of alternatives. Due to differences in delivery and orientation, line charges are not included within these three ranges of NEW, and their potential effects were analyzed and presented separately. A discussion of the equations used and environmental provinces and equations used is provided in Appendix A, Supplemental Information for Underwater Noise Analysis, and Appendix B, Geographic Description of Acoustic Environmental Provinces.

Table 6-5. Explosive Noise Criteria and Thresholds for Marine Mammals

Harassment Level	Criterion	Threshold
Level A Harassment	Onset of severe lung injury	"Goertner" modified positive impulse indexed to 31 psi-ms
Injury	Tympanic Membrane Rupture	50% Rate of Rupture 205 dB re 1 μPa^2-s
Injury	Onset of Slight Lung Injury	Goertner Modified Positive Impulse Indexed to 13 psi-ms
Level B Harassment Non-Injury	TTS	182 dB re 1 μPa^2-s (energy flux density) in any 1/3-octave band at frequencies above 100 Hz for all toothed whales (e.g., sperm whales and beaked whales); above 10 Hz for all baleen whales
Non-injury dual criterion	Onset of TTS	23 psi peak pressure level (for small explosives)
Behavioral Modification	Successive Detonations Only (Sub TTS)	177 dB re 1 μPa^2-s (energy flux density) in any 1/3-octave band at frequencies above 100 Hz for all toothed whales; above 10 Hz for all baleen whales

* Odontocetes = toothed whales, including dolphins; Sirenians = manatees; Mysticetes = baleen whales; hz = Hertz
These criteria were applied to all detonations including line charges, which are comprised of a 107 m (350 ft) detonation cord with explosives lined from one end to the other end in 2 kg (5 lb) increments.

Analysis for mine-clearing line charges followed methods similar to detonations. The major differences in the line charge analysis included (1) focus on propagation through the sediment layer(s) rather than treating the bottom as a boundary with a particular reflection loss and

(2) modeling according to its unique physical characteristics. The specific information on calculations for mine-clearing line charges is presented in Appendix A, Supplemental Information for Underwater Noise Analysis.

Acoustical modeling is a conservative measure of the actual exposures and, therefore, the numbers presented in the following paragraphs are not necessarily indicative of actual exposures under the MMPA. In an effort to reduce the potential exposures associated with live detonations, the mitigation and protective measures will be implemented.

6.3.3 Marine Mammal Exposures

Detonations in territorial waters may expose up to three bottlenose dolphins and three Atlantic spotted dolphins to sound likely to result in harassment (Table 6-6). The only potential impacts to marine mammals will occur at Level B harassment.

Table 6-6. Estimates of Marine Mammal Exposures from Detonations in Territorial Waters Per Year

Marine Mammal Species	Level A (Severe Lung Injury)	Level A (Slight Lung Injury)	Level B (Non-Injury)
Bottlenose dolphin	0	0	3
Atlantic spotted dolphin	0	0	3
Combined bottlenose and Atlantic spotted dolphins*	0	0	0

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys

The use of line charges under Alternative 2 may expose up to one Atlantic spotted dolphin to sound likely to result in harassment (Table 6-7). The only potential impacts to any marine mammal species will occur at Level B harassment.

Table 6-7. Estimates of Marine Mammal Exposures from Line Charges (794 kg [1,750 lb]) in Territorial Waters Per Year

Marine Mammal Species	Level A (Severe Lung Injury)	Level A (Slight Lung Injury)	Level B (Non-Injury)
Bottlenose dolphin	0	0	0
Atlantic spotted dolphin	0	0	1
Combined bottlenose and Atlantic spotted dolphins*	0	0	0

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys

Detonations in non-territorial waters may expose up to seven marine mammal species to sound likely to result in Level B harassment (Table 6-10). They include the sperm whale, Risso's dolphin, rough-toothed dolphin, bottlenose dolphin, Atlantic spotted dolphin, pantropical spotted dolphin, and spinner dolphin. In addition, one bottlenose dolphin, one Atlantic spotted dolphin and one pantropical spotted dolphin may be exposed to levels of sound likely to result in Level A harassment.

Table 6-8. Estimates of Marine Mammal Exposures from Detonations in Non-territorial Waters Per Year

Marine Mammal Species	Level A (Severe Lung Injury)	Level A (Slight Lung Injury)	Level B (Non-Injury)
Bryde's whale	0	0	0
Sperm whale	0	0	1
Dwarf/Pygmy sperm whale	0	0	0
All beaked whales	0	0	0
Killer whale	0	0	0
False killer whale	0	0	0
Pygmy killer whale	0	0	0
Risso's dolphin	0	0	1
Rough-toothed dolphin	0	0	1
Bottlenose dolphin	0	1	10
Atlantic spotted dolphin	0	1	10
Combined bottlenose and Atlantic spotted dolphins*	0	0	0
Pantropical spotted dolphin	0	1	6
Striped dolphin	0	0	0
Spinner dolphin	0	0	7
Clymene dolphin	0	0	0
Unidentified *Stenella***	0	0	0
Fraser's dolphin	0	0	0

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys
**Unidentified *Stenella* includes pantropical spotted, striped, spinner, and Clymene dolphins that were not differentiated during scientific surveys.

6.3.4 Summary of Potential Acoustic Effects from Detonations by Marine Mammal Species

Acoustical modeling provides an estimate of the actual exposures. In an effort to reduce the potential exposures associated with live detonations, the mitigation and protective measures listed in Chapter 5 will be implemented.

Territorial Waters

The Atlantic spotted dolphin and bottlenose dolphin are the only marine mammals that occur in territorial waters. The acoustic analysis shows that exposures may occur to both species. The following subsections discuss the potential effects to dolphin species from explosive events associated with NSWC PCD RDT&E activities.

Atlantic Spotted Dolphins

The best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins (Waring et al., 2007). For Atlantic spotted dolphins, four individuals will be exposed to levels of sound likely to result in Level B harassment. Based on the exposure data and the best estimate of abundance, 0.01 percent of the northern GOM stock of Atlantic spotted dolphins will be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science and the best estimate of abundance, the Navy concludes that exposures to Atlantic spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Atlantic spotted dolphins.

Bottlenose Dolphins

In the northern GOM, there are three coastal stocks of bottlenose dolphin; a continental shelf stock; an oceanic stock; and numerous bay, sound, and estuarine stocks. It is believed that many of these different stocks may overlap each other. The best estimate of abundance along the GOM continental shelf and slope is 25,320, with a minimum population estimate of 20,414 bottlenose dolphins (Waring et al., 2007).

Analysis for detonations indicated that three bottlenose dolphins will be exposed to levels of sound likely to result in Level B harassment. Based on the exposure data and the best estimate of abundance, 0.01 percent of the northern GOM continental shelf and slope bottlenose dolphins will be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science, the Navy concludes that exposures to bottlenose dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to bottlenose dolphins.

Non-Territorial Waters

The following subsections present the summary for species with potential to be exposed to sound based on the previous acoustic analysis. Information is presented for only those species with the potential to be exposed. There will be no significant harm from detonations to any of the other marine mammal species that may occur in the non-territorial waters of the NSWC PCD Study Area.

Sperm Whale

The best abundance estimate for sperm whales in the northern GOM is 1,349, with a minimum population estimate of 1,114. There has been no directed research program on sperm whales in the United States since 1970, and information is limited to survey sighting reports, stranding records, and a handful of isolated studies (Lowry et al., 2007). Abundance information, population dynamics, and trends are extremely limited for sperm whale populations in U.S. waters (Lowry et al., 2007).

Explosives analysis indicated that one sperm whale will be exposed to levels of sound likely to result in Level B harassment. Based on the exposure data and the best estimate of abundance, it is estimated that 0.074 percent of the northern GOM stock of sperm whales will potentially be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science, the Navy concludes that exposures to sperm whales due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to sperm whales.

Risso's Dolphin

The best estimate of abundance for Risso's dolphins in the northern GOM is 2,169, with a minimum population estimate of 1,668 Risso's dolphins (Waring et al., 2007). Explosives analysis indicated that one Risso's dolphin will be exposed to levels of sound likely to result in Level B harassment. Therefore, based on the active sonar exposure data and the best estimate of abundance, it is estimated that 0.05 percent of the northern GOM stock of Risso's dolphin may be exposed to levels of sound likely to result in Level B.

Based on the best available science, the Navy concludes that exposures to Risso's dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Risso's dolphins.

Rough-Toothed Dolphin

The best estimate of abundance for rough-toothed dolphins is 2,223 in the northern GOM. The minimum population estimate for the same area is 1,595 rough-toothed dolphins. Explosives analysis indicated that one individual will be exposed to levels of sound likely to result in Level B harassment. The best estimate for the northern GOM stock of rough--toothed dolphins is 2,223 (Waring et al., 2007). Therefore, based on the exposure data and the best estimate of abundance, it is estimated that 0.04 percent of the northern GOM stock of rough-toothed dolphins will be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science, the Navy concludes that exposures to rough-toothed dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to rough-toothed dolphins.

Atlantic Spotted Dolphins

As previously mentioned, the best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins (Waring et al., 2007). Explosive analysis indicated that up to ten Atlantic spotted dolphins would be exposed. The assumption is conservatively made to count the one combined bottlenose and Atlantic spotted dolphin for each group. Based on the analysis and the best estimate of abundance, 0.03 percent of animals will be exposed to levels of sound likely to result in Level B harassment. These exposures will not necessarily occur to different individuals as the same individuals could be exposed multiple times over the duration of the sonar tests. Thus, the estimated number of pantropical and Atlantic spotted dolphins experiencing harassment may be fewer than previously stated. Up to one Atlantic spotted dolphins may be exposed to sound likely to result in Level A harassment from slight lung injury. Based on the analysis and the best estimate of abundance, 0.003 percent of animals will be exposed to levels of sound likely to result in Level A harassment from slight lung injury.

Based on the best available science, the Navy concludes that exposures to Atlantic spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Atlantic spotted dolphins.

Pantropical Spotted Dolphins

Explosive analysis indicated that up to six pantropical spotted dolphins will be exposed to levels of sound likely to result in Level B harassment. These exposures will not necessarily occur to different individuals as the same individuals could be exposed multiple times over the duration of the sonar tests. Thus, the estimated number of pantropical and Atlantic spotted dolphins experiencing harassment may be fewer than previously stated.

The best estimate of abundance for pantropical spotted dolphins in the northern GOM is 91,321, with a minimum population of 79,879 dolphins (Waring et al., 2007). Therefore, based on the exposure data and the best estimate of abundance, it is estimated that 0.007 percent of the northern GOM stock of pantropical spotted dolphins will potentially be exposed to levels of sound likely to result in Level B harassment. Up to one pantropical spotted dolphin may be exposed to sound likely to result in Level A harassment from slight lung injury. Based on the analysis and the best estimate of abundance, 0.001 percent of northern GOM stock of pantropical spotted dolphins will potentially be exposed to levels of sound likely to result in Level A harassment from slight lung injury.

Based on the best available science, the Navy concludes that exposures to pantropical spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to pantropical spotted dolphins.

Bottlenose Dolphin

Analysis for detonations indicated that ten bottlenose dolphins will be exposed to levels of sound likely to result in Level B harassment. This takes into account the one exposure for the combined Atlantic spotted and bottlenose dolphin category. As presented in the territorial section, the best estimate of abundance along the GOM continental shelf and slope is 25,320, with a minimum population estimate of 20,414 bottlenose dolphins (Waring et al., 2007). Based on the exposure data and the best estimate of abundance, 0.04 percent of the northern GOM continental shelf and slope bottlenose dolphins will be exposed to levels of sound likely to result in Level B harassment. In addition, one bottlenose dolphin may be exposed to sound likely to result in Level A harassment from slight lung injury. Based on the analysis and the best estimate of abundance, 0.0003 percent of northern GOM continental shelf and slope bottlenose dolphins will potentially be exposed to levels of sound likely to result in Level A harassment from severe lung injury.

Based on the best available science, the Navy concludes that exposures to bottlenose dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to bottlenose dolphins.

Spinner Dolphin

The best estimate of abundance for spinner dolphins in the northern GOM is 11,971. The minimum population estimate is 6,990 spinner dolphins. Explosives analysis indicated that up to seven spinner dolphins will be exposed to levels of sound likely to result in Level B harassment. The best estimate for the northern GOM stock of spinner dolphins is 11,971 (Waring et al., 2007). Therefore, based on the exposure data and the best estimate of abundance, it is estimated that 0.06 percent of spinner dolphins will be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science, the Navy concludes that exposures to spinner dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to spinner dolphins.

6.4 ACOUSTIC AND NON-ACOUSTIC EFFECTS: PROJECTILE FIRING

6.4.1 Introduction and Approach to Analysis

Projectile firing includes the use of inert rounds of ammunition as well as high-explosive (HE) 5-in gun-rounds. The primary concern with respect to projectile firing and marine mammals encompasses the potential sound effects associated with their expenditures. Therefore, the following analysis focuses on the live 5-inch gun rounds. The same thresholds were used to analyze projectile firing as the previous section on ordnance operations. Modeling took into account the firing of single shots separated in time.

6.4.2 Marine Mammal Exposures

Live projectile firing operations will not occur in territorial waters.

Five-inch round testing will increase to 60 live projectiles annually. Projectile firing in non-territorial waters may expose up to three species of marine mammals to sound likely to result in Level B harassment (Table 6-9). They include the Atlantic spotted dolphin, striped dolphin and spinner dolphin. The only potential impacts to marine mammals will occur at Level B harassment.

Table 6-9. Estimates of Marine Mammal Exposures from 5-inch Round Detonations in Non-territorial Waters

Marine Mammal Species	Level A (Severe Lung Injury)	Level A (Slight Lung Injury)	Level B (Non-Injury)
Bryde's whale	0	0	0
Sperm whale	0	0	0
Dwarf/Pygmy sperm whale	0	0	0
All beaked whales	0	0	0
Killer whale	0	0	0
False killer whale	0	0	0
Pygmy killer whale	0	0	0
Risso's dolphin	0	0	0
Rough-toothed dolphin	0	0	0
Bottlenose dolphin	0	0	0
Atlantic spotted dolphin	0	0	1
Combined bottlenose and Atlantic spotted dolphin*	0	0	0
Pantropical spotted dolphin	0	0	0
Striped dolphin	0	0	1
Spinner dolphin	0	0	1
Clymene dolphin	0	0	0
Unidentified *Stenella***	0	0	0
Fraser's dolphin	0	0	0

*Combined bottlenose and Atlantic spotted dolphins includes individuals that were not differentiated during scientific surveys
**Unidentified *Stenella* includes pantropical spotted, striped, spinner, and clymene dolphins that were not differentiated during scientific surveys.

6.4.3 Summary of Potential Acoustic Effects from Projectile Firing by Marine Mammal Species

Non-Territorial Waters

Acoustical modeling provides an estimate of the actual exposures. In an effort to reduce the potential exposures associated with live projectile firing, the mitigation and protective measures listed in Chapter 5 will be implemented.

Atlantic Spotted Dolphin

The best estimate of abundance for Atlantic spotted dolphins in the northern GOM is 30,947, with a minimum population estimate of 24,752 dolphins (Waring et al., 2007). Analysis for projectile firing indicated that up to one Atlantic spotted dolphin would be exposed to levels of sound likely to result in Level B (behavioral) harassment. Based on the analysis and the best estimate of abundance, 0.003 percent of animals will be exposed to levels of sound likely to result in Level B harassment. These exposures will not necessarily occur to different individuals as the same individuals could be exposed multiple times over the duration of the sonar tests. Thus, the estimated number of Atlantic spotted dolphins experiencing harassment may be fewer than previously stated.

Based on the best available science, the Navy concludes that exposures to Atlantic spotted dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to Atlantic spotted dolphins.

Striped Dolphin

The best abundance estimate for striped dolphins in the northern GOM is 6,505, with a minimum population estimate of 4,599 striped dolphins (Waring et al., 2007). Analysis for projectile firing indicated that one striped dolphin will be exposed to levels of sound likely to result in Level B (behavioral) harassment. Based on this exposure data and the best estimate of abundance, 0.02 percent of the northern GOM stock of striped dolphin would potentially be exposed to levels of sound likely to result in Level B (behavioral) harassment.

Based on the best available science, the Navy concludes that exposures to striped dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to striped dolphins.

Spinner Dolphin

The best estimate of abundance for spinner dolphins in the northern GOM is 11,971. The minimum population estimate is 6,990 spinner dolphins. Analysis for projectile firing indicated that up one spinner dolphin will be exposed to levels of sound likely to result in Level B (behavioral) harassment. The Navy evaluated potential exposures to stocks based on the best estimate for each stock of marine mammal species. Therefore, based on the exposure data and the best estimate of abundance, it is estimated that 0.008 percent of spinner dolphins will be exposed to levels of sound likely to result in Level B harassment.

Based on the best available science, the Navy concludes that exposures to spinner dolphins due to NSWC PCD RDT&E activities would result in short-term effects to most individuals exposed and would likely not affect annual rates of recruitment or survival. The mitigations presented in Chapter 11 will further reduce the potential for exposures to occur to spinner dolphins.

6.4.4 Potential Non-Acoustic Effects from Projectile Firing

NSWC PCD RDT&E activities include projectile firing, which has the potential to directly strike marine mammals. Small arms rounds are tested through firing at a fixed target. Firing will occur at close range in relation to the target.

Territorial Waters – Marine Mammals (Projectile Firing)

No projectile firing will occur in territorial waters of the NSWC PCD Study Area.

Non-territorial Waters – Marine Mammals (Projectile Firing)

As previously described, tests involving projectile firing are conducted at close range. The likelihood is low that a marine mammal will enter the firing area directly adjacent to the target undetected simultaneous to projectile firing. The noise associated with the firing and the support aircraft and/or surface vessels would likely cause animals to avoid the area. Furthermore, the mitigation and clearance procedures identified in Chapter 5 will be implemented. Large groups of cetaceans such as schools of dolphin species and large species of whales such as sperm whales and Bryde's whales will be sighted at the surface during standard clearance procedures and avoided. Based on the best available science and the implementation of projective measures, the Navy concludes that direct physical impact from projectile firing would not likely affect annual rates of recruitment or survival.

This page is intentionally blank.

7. EFFECTS TO MARINE MAMMAL SPECIES OR STOCKS

Overall, the conclusions in this analysis find that effects to marine mammal species and stocks would be negligible for the following reasons:

- Most acoustic exposures are within the non-injurious Temporary Threshold Shift (TTS) or behavioral effects zones (Level B harassment).
- Although the estimated exposure numbers represent estimated harassment under the Marine Mammal Protection Act (MMPA), as described above, they are conservative estimates of harassment, primarily by behavioral disturbance. In addition, the model calculates harassment without taking into consideration standard protective measures, and is not indicative of a likelihood of either injury or harm.
- Additionally, the protective measures described in Chapter 11 are designed to reduce sound exposure of marine mammals to levels below those that may cause "behavioral disruptions" and to achieve the least practicable adverse effect on marine mammal species or stocks.

Consideration of negligible impact is required for the National Marine Fisheries Service (NMFS) to authorize incidental take of marine mammals. By definition, an activity has a "negligible impact" on a species or stock when it is determined that the total taking is not likely to reduce annual rates of adult survival or recruitment (i.e., offspring survival, birth rates). An analysis of the potential impacts of the Proposed Action on species recruitment or survival is presented in Chapter 6 for each species, based on each species' life history information, the characteristics of the Naval Surface Warfare Center Panama City Division (NSWC PCD) mission locations, and an analysis of the behavioral disturbance levels in comparison to the overall population. These species-specific analyses support the conclusion that NSWC PCD events would have a negligible impact on marine mammals.

7.1 SURFACE OPERATIONS

The use of vessels during NSWC PCD RDT&E activities will not take any marine mammals in territorial or non-territorial waters.

7.2 SONAR

No takings by death or injury of marine mammals are anticipated from missions that test sonar in the Gulf of Mexico (GOM). Takings by incidental harassment may occur to the species that occur in territorial waters, bottlenose and Atlantic spotted dolphins, while twelve species of marine mammals may be taken by incidental harassment in non-territorial waters. They include the Bryde's whale (*Balaenoptera edeni*), sperm whale (*Physeter macrocephalus*), false killer whale (*Pseudorca crassidens*), Risso's dolphin (*Grampus griseus*), rough-toothed dolphin (*Steno bredanensis*), bottlenose dolphin (*Tursiops truncatus*), Atlantic spotted dolphin (*Stenella frontalis*), pantropical spotted dolphin (*Stenella attenuata*), striped dolphin (*Stenella coeruleoalba*), spinner dolphin (*Stenella longirostris*), Clymene dolphin (*Stenella clymene*), and Fraser's dolphin (*Lagenodelphis hosei*). Because sonar testing in the NSWC PCD Study Area results in temporary and intermittent takings by incidental harassment, there will be a negligible effect to affected species or stocks. In addition, sonar operations in non-territorial waters may expose up to one bottlenose dolphin (*Tursiops truncatus*), Atlantic spotted dolphin (*Stenella frontalis*), and pantropical spotted dolphin (*Stenella attenuata*) to levels of sound likely to result in TTS.

7.3 ORDNANCE

The taking by incidental harassment of marine mammals in territorial waters from explosive testing is limited to the two dolphin species that occur here – the bottlenose dolphin (*Tursiops truncatus*) and the Atlantic spotted dolphin (*Stenella frontalis*). Exposures from this activity leading to slight or severe lung injury are not expected.

The taking by incidental harassment of marine mammals is expected from the testing of ordnance in non-territorial waters. The taking by slight lung injury is limited to only three species, the bottlenose dolphin (*Tursiops truncatus*), the Atlantic spotted dolphin (*Stenella frontalis*), and pantropical spotted dolphin (*Stenella attenuata*). Exposures from this activity leading to severe lung injury are not expected. The taking by incidental harassment is anticipated for seven species including the sperm whale (*Physeter macrocephalus*), Risso's dolphin (*Grampus griseus*), rough-toothed dolphin (*Steno bredanensis*), bottlenose dolphin (*Tursiops truncatus*), Atlantic spotted dolphin (*Stenella frontalis*), pantropical spotted dolphin (*Stenella attenuata*), and spinner dolphin (*Stenella longirostris*).

7.4 PROJECTILE FIRING

Testing of projectile firing using 5-inch gun rounds in non-territorial waters creates only takings by incidental harassment of three species of dolphins, including the Atlantic spotted dolphin (*Stenella frontalis*), the striped dolphin (*Stenella coeruleoalba*), and the spinner dolphin (*Stenella longirostris*). Overall, the number of takings is low and only results in takings by incidental harassment, which is temporary and intermittent. Thus, a negligible effect to affected species or stocks is anticipated.

8. MINIMIZATION OF ADVERSE EFFECTS TO SUBSISTENCE USE

Potential impacts resulting from the proposed activity will be limited to individuals of marine mammal species located in the Gulf of Mexico (GOM), and will not affect Arctic marine mammals. No subsistence uses exist for cetacean species occurring in waters affected by the Proposed Action. Since Naval Surface Warfare Center Panama City Division (NSWC PCD) activities will not take place in Arctic waters, these activities would not have an unmitigable adverse impact on the availability of marine mammals for subsistence uses identified in Marine Mammal Protection Act (MMPA) Section 101(a)(5)(A)(i). Therefore, no impacts are anticipated to targeted species or stocks available for Native American subsistence use.

This page is intentionally blank.

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

The Naval Surface Warfare Center Panama City Division (NSWC PCD) Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS) considered the sources that could affect marine mammal habitat. Sources that may affect marine mammal habitat include changes in water quality from expended materials, introduction of sound into the water column, and transiting vessels. Each of these components was considered in the NSWC PCD EIS/OEIS and was determined to have no effect on marine mammal habitat. A summary of the conclusions are included in subsequent sections. Changes in the amount and distribution of prey were also analyzed relative to these operations to determine whether effects to marine mammal habitat would occur. Marine mammal habitat would not be affected.

9.1 WATER QUALITY

The NSWC PCD EIS/OEIS analyzed the potential effects to water quality from Research, Development, Test, and Evaluation (RDT&E) activities. There is a possibility of affecting water quality through the release of explosion products, leaching of metals, and increased turbidity. It was determined that there would be no significant effect to water quality.

The majority of sediment displaced by an explosion will originate from the affected area created on the sea floor. For small explosions, sediments will be expected to settle out by the completion of the operations, but for larger explosions, sediments may stay suspended for hours. Due to mixing and continued dilution, explosion products will be reduced to undetectable levels. The gaseous products will not affect water quality beyond an extremely short time period in the close vicinity of the test. Explosion products either will dissipate rapidly into surrounding waters or are physiologically inert, and no water quality criteria will be exceeded.

Line charges will only occur in the surf zone, which already is characterized by significant turbidity. Furthermore, locations of line charges occur in areas of wave action; therefore, turbid waters will dissipate within hours of the operation. All other detonations will occur within the water column, not on the sea floor. Bottom sediments will not be affected by detonations occurring within the water column.

After detonation, the majority of fragments from steel mine casings will be recovered in order to evaluate the success of the test; however, a small number of metal fragments (steel and aluminum) from the detonation of live mines and ordnance may be left on the sea floor. The few pieces that may remain on the sea floor will likely settle into the oxygen-poor bottom sediments where they may slowly corrode.

The NSWC PCD EIS/OEIS analyzed the potential effects to water quality. Effects related to water quality would be localized and temporary based on the characteristics of the currents and water movement in the NSWC PCD Study Area. Explosion products either will dissipate rapidly into surrounding waters or are physiologically inert, and no water quality criteria will be exceeded as a result of the level of detonations associated with the Proposed Action. For the reasons outlined above, it was determined that there would be no significant effect to water quality from the release of explosion products, leaching of metals, or increased turbidity. Finally, the Navy would avoid sensitive marine habitats such as seagrass, *Sargassum*, and hardbottom.

Projectile firing will also take place during NSWC PCD RDT&E activities. Most of the activities, including all activities in territorial waters, involve inert firing. Inert projectile firing consists of the use of a solid round that will not introduce constituents into the water. Therefore, no analysis will be required for inert firing. In non-territorial waters, NSWC PCD RDT&E activities will include live projectile firing (naval ammunition). Therefore, the live rounds are included in the water quality analysis because constituents in the projectiles (e.g., tungsten, lead, and aluminum powder) will be immediately available in the environment. These materials will likely become lodged in the oxygen-poor sediments of the sea floor, exhibiting a high degree of corrosion resistance for the metals contained within the tungsten rounds. It is highly unlikely that all constituents in the ammunition will be immediately available for aquatic species to transfer, ingest, or absorb. Therefore, it was determined that there would be no significant effect to water quality from projectile firing in non-territorial waters.

9.2 SOUND IN THE ENVIRONMENT

The potential cumulative impact issue associated with active sonar activities is the addition of underwater sound to oceanic ambient noise levels, which in turn could have potential effects on marine animals. Anthropogenic sources of ambient noise that are most likely to have contributed to increases in ambient noise levels are commercial shipping, offshore oil and gas exploration and drilling, and naval and other use of sonar (Department of the Navy [DON], 2007a). The potential impact that mid- and high-frequency sonars may have on the overall oceanic ambient noise level are reviewed in the following contexts:

- Recent changes to ambient sound levels in the Gulf of Mexico (GOM);
- Operational parameters of the sonar operating during RDT&E activities, including proposed mitigation;
- The contribution of active sonar activities to oceanic noise levels relative to other human-generated sources of oceanic noise; and
- Cumulative impacts and synergistic effects.

Very few studies have been conducted to determine ambient sound levels in the ocean. However, ambient sound levels for the Eglin Gulf Test and Training Range, located in the GOM, generally range from approximately 40 decibels (dB) to about 110 dB (United States [U.S.] Air Force, 2002). In a study conducted by Andrew et al. (2002), ocean ambient sound from the 1960s was compared to ocean ambient sound from the 1990s for a receiver off the coast of California (DON, 2007d). The data showed an increase in ambient noise of approximately 10 dB in the frequency range of 20 to 80 hertz (Hz) and 200 and 300 Hz, and about 3 dB at 100 Hz over a 33-year period (DON, 2007d).

Anthropogenic sound can be introduced into the ocean by a number of sources, including vessel traffic, industrial operations onshore, seismic profiling for oil exploration, oil drilling, and sonar operation. In open oceans, the primary persistent anthropogenic sound source tends to be commercial shipping, since over 90 percent of global trade depends on transport across the seas (Scowcroft et al., 2006). Moreover, there are approximately 20,000 large commercial vessels at sea worldwide at any given time. The large commercial vessels produce relatively loud and predominately low-frequency sounds. Most of these sounds are produced as a result of propeller cavitation (when air spaces created by the motion of propellers collapse) (Southall, 2005). In 2004, the National Oceanic and Atmospheric Administration (NOAA) hosted a symposium entitled, "Shipping Noise and Marine Mammals." During Session I, Trends in the Shipping Industry and Shipping Noise, statistics were presented that indicate foreign waterborne trade into the United States has increased 2.45 percent each year over a 20-year period (1981-2001) (Southall, 2005). International shipping volumes and densities are expected to continually increase in the foreseeable future (Southall, 2005). The increase in shipping volumes and densities will most likely increase overall ambient sound levels in the ocean. However, it is not known whether these increases would have an effect on marine mammals (Southall, 2005).

According to the National Research Council (NRC) (2003), the oil and gas industry has five categories of activities which create sound: seismic surveys, drilling, offshore structure emplacement, offshore structure removal, and production and related activities. Seismic surveys are conducted using air guns, sparker sources, sleeve guns, innovative new impulsive sources and sometimes explosives, and are routinely conducted in offshore exploration and production operations in order to define subsurface geological structure. The resultant seismic data are necessary for determining drilling location and currently seismic surveys are the only method to accurately find hydrocarbon reserves. Since the reserves are deep in the earth, the low frequency band (5 to 20 Hz) is of greatest value for seismic surveys, because lower frequency signals are able to travel farther into the seafloor with less attenuation (DON, 2007d).

Air gun firing rate is dependent on the distance from the array to the substrate. The typical intershot time is 9 to 14 seconds, but for very deep water surveys, inter-shot times are as high as 42 sec. Air gun acoustic signals are broadband and typically measured in peak-to-peak pressures. Peak levels from the air guns are generally higher than continuous sound levels from any other ship or industrial noise. Broadband SLs of 248 to 255 dB from zero-to-peak are typical for a full-scale array. The most powerful arrays have source levels as high as 260 dB, zero-to-peak with air gun volumes of 130 L (7,900 cubic inches). Smaller arrays have SLs of 235 to 246 dB, zero-to-peak.

For deeper-water surveys, most emitted energy is around 10 to 120 Hz. However, some pulses contain energy up to 1,000 Hz (Richardson et al., 1995), and higher. Drill ship activities are one of the noisiest at-sea operations because the hull of the ship is a good transmitter of all the ship's internal noises. Also, the ships use thrusters to stay in the same location rather than anchoring. Auxiliary noise is produced during drilling activities, such as helicopter and supply boat noises. Offshore drilling structure emplacement creates some localized noise for brief periods of time, and emplacement activities can last for a few weeks and occur worldwide. Additional noise is created during other oil production activities, such as borehole logging, cementing, pumping, and pile driving. Although sound pressure levels for some of these activities have not yet been calculated, others have (e.g., pile-driving). More activities are occurring in deep water in the GOM. These oil and gas industry activities occur year-round (not individual surveys, but collectively) and are usually operational 24 hours per day and seven days a week.

There are both military and commercial sonars: military sonars are used for target detection, localization, and classification; and commercial sonars are typically higher in frequency and lower in power and are used for depth sounding, bottom profiling, fish finding, and detecting obstacles in the water. Commercial sonar use is expected to continue to increase, although it is not believed that the acoustic characteristics will change (DON, 2007d). Even though an animal's exposure to active sonar may be more than one time, the intermittent nature of the sonar signal, its low duty cycle, and because both the vessel and animal are moving provide only a small chance that exposure to active sonar for individual animals and stocks would be repeated over extended periods of time, such as those caused by shipping noise. Moreover, it was determined in the NSWC PCD EIS/OEIS that active sonar transmissions will not significantly increase anthropogenic oceanic noise. Mitigation measures will be employed during NSWC PCD RDT&E activities to minimize potential effects to marine mammals to the greatest extent practicable. As such, it was determined that there would be no significant effect to marine mammals from sound in the environment.

9.3 TRANSITING VESSELS

Collisions with commercial and U.S. Navy ships can cause major wounds and may occasionally cause fatalities to marine mammals. The most vulnerable marine mammals are those that spend extended periods of time at the surface in order to restore oxygen levels within their tissues after deep dives (e.g., the sperm whale). In addition, some baleen whales, such as the North Atlantic right whale, seem generally unresponsive to ship sound, making them more susceptible to ship strikes (Nowacek et al., 2004). These species are primarily large, slow moving whales. Smaller marine mammals, for example Atlantic bottlenose and Atlantic spotted dolphins, move quickly throughout the water column and are often seen riding the bow wave of large ships. Marine mammal responses may include avoidance and changes in dive pattern (NRC, 2003).

Accordingly, the U.S. Navy has adopted standard operating procedures and mitigation measures to reduce the potential for collisions with surfaced marine mammals (for more details refer to Chapter 11). These include:

- Using lookouts trained to detect all objects on the surface of the water, including marine mammals.
- Implementing reasonable and prudent actions to avoid the close interaction of Navy assets and marine mammals.
- Maneuvering to keep away from any observed marine mammal.

NSWC PCD RDT&E activities incorporate a variety of marine craft including the Athena 1, Athena 2, Research Vessel (R/V) Mr. Offshore, several 4.0 to 7.6 m (13 to 25 ft) outboard motor boats, a 9.1 m (30 ft) rigid hull inflatable boat (RHIB), and 9.8 m (32 ft), 20 m (65 ft), and 21 m (68 ft) inboard diesel vessels. Large surface vessels associated with the RDT&E activities are present; however, typically they transit to and from a test location and are stationary for a large proportion of operations. Thus, effects to marine mammal habitat from these vessels would be negligible.

This page is intentionally blank.

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

Based on the previous discussion in this Letter of Authorization (LOA) request, there will be no effects to marine mammals resulting from loss or modification of marine mammal habitat.

This page is intentionally blank.

11. MEANS OF EFFECTING THE LEAST PRACTICABLE ADVERSE IMPACTS – MITIGATION MEASURES

The Naval Surface Warfare Center Panama City Division (NSWC PCD) identified protective measures to reduce any potential risks to marine mammals. The actions described in this request will present a potential risk to marine mammals. Mitigations and monitoring will limit the number of exposures.

11.1 ENVIRONMENTAL REVIEW PROCESS

The NSWC PCD Environmental Review Process (ERP), as implemented by the revised NSWC PCD Instruction 5100.30D, requires that all draft test plans be submitted to the NSWC PCD Environmental Help Desk six months prior to the proposed start date. The test plan is assigned an environmental analyst from the Help Desk to review the proposed testing.

Upon completing the review of the test plan, the assigned analyst would make a determination as to whether the proposed testing falls within the overall scope of the NSWC PCD EIS/OEIS or has sufficient environmental documentation to cover the Proposed Action. If it is determined that the proposed testing is either covered under the scope of the NSWC PCD EIS/OEIS and this LOA request or has sufficient independent environmental planning documentation, the analyst would prepare a Record of Environmental Consideration (REC), which would serve as documentation that the plan successfully completed the ERP and would not require any further environmental review.

However, if it is determined that the proposed testing falls outside of the scope of the NSWC PCD EIS/OEIS, does not have current environmental planning documentation, and does not meet the criteria for utilizing one of the Navy's Categorical Exclusions (CATEXs), the Help Desk analyst would contact the test planner immediately. The Help Desk analyst would request that the test planner present a short informational briefing on the proposed testing to the Environmental Review Board. The Environmental Review Board serves as the official forum for determining what actions would be required if a proposed test falls outside the scope of the NSWC PCD EIS/OEIS. A REC would be provided to the test planner describing the level of environmental compliance documentation required and outlining any specific mitigation, agency coordination, or recommended safety procedures. The mitigations and recommendations would be incorporated into the individual test plans to ensure compliance. The ERP would incorporate these mitigations and recommendations based on the nature of the test event such as the test platforms (i.e. aircraft, surface vessel) and the acoustic sources (i.e., sonars, explosives, and projectiles) and their associated environmental effects addressed in this EIS/OEIS. Each of the mitigations outlined in this chapter would be applied appropriately to each test event.

In an effort to track and monitor the activity tempos associated with the effects addressed in the NSWC PCD EIS/OEIS and this LOA request, test directors would be required to submit a Post-test Summary to the NSWC PCD Environmental Help Desk upon the completion of each test event. The Post-test Summary would summarize the test events, any protective measures used, an overview of marine mammal and sea turtle observations and capture the actual hours, intensity, and number of events conducted. The data captured would be used to populate a living database that would be used to compare NSWC PCD's current operational tempo and intensity to that which has been analyzed in the EIS/OEIS and this LOA request. Thus, this data would serve as a means of projecting if and when NSWC PCD operations might exceed the allotment of hours utilized in the analysis performed within the NSWC PCD EIS/OEIS and this LOA request.

11.2 MITIGATION MEASURES RELATED TO SURFACE OPERATIONS

Visual surveys will be conducted for all test operations to reduce the potential for vessel collisions with a protected species. If necessary, the ship's course and speed will be adjusted.

11.3 MITIGATION MEASURES RELATED TO EFFECTS FROM SONAR

To meet current and future national and global defense challenges, the Navy must develop a robust capability using realistic conditions to research, develop, test, and evaluate systems within the NSWC PCD Study Area. The Navy recognizes that such developments have the potential to create serious injury and/or mortality and to cause behavioral disruption of some marine mammal species in the vicinity of research, development, test, and evaluation (RDT&E) activities. This chapter presents the Navy's mitigation measures that will be implemented to protect marine mammals, federally listed species, and other aspects of the marine environment during RDT&E activities. Several of these mitigation measures align with protective measures in the training arena for the Navy, which have been in place since 2004.

11.3.1 Personnel Training

NSWC PCD has used Navy marine observers in previous RDT&E test activities that have the potential to affect protected marine species. Depending on the level of activity and the projected potential effects, the observers are required to sight and report to the Test Director any marine mammal or sea turtle species within 914 m (1,000 yd) of the sonar dome. Marine observers also keep detailed records about the time and duration of sonar use, the location of testing, and any species observed during the sonar activities. These Navy marine observers either undergo extensive Navy training to qualify or have educational and professional experience as biologists, typically specializing in marine mammal biology or marine biology in general.

Marine mammal mitigation training for those who participate in the active sonar activities is a key element of the mitigation measures. The goal of this training is for key personnel onboard Navy platforms in the NSWC PCD Study Area to understand the mitigation measures and be competent to carry them out. The Marine Species Awareness Training (MSAT) is provided to all applicable participants, where appropriate. The program addresses environmental protection, laws governing the protection of marine species, Navy stewardship, and general observation information including more detailed information for spotting marine mammals. Marine mammal observer training will also be provided before active sonar testing begins. MSAT has been reviewed by the National Marine Fisheries Service (NMFS) and acknowledged as suitable training. MSAT will be provided to participants, as deemed needed and appropriate during the

ERP. Marine observers will be aware of the specific actions to be taken based on the RDT&E platform if a marine mammal or sea turtle is observed.

11.3.2 Range Operating Procedures

The following procedures will be implemented to maximize the ability of Navy personnel to recognize instances when marine mammals are in the vicinity.

11.3.2.1 General Maritime Protective Measures: Personnel Training

Marine observers will be trained to quickly and effectively communicate within the command structure to facilitate implementation of protective measures if marine mammals are spotted.

11.3.2.2 General Maritime Protective Measures: Observer Responsibilities

- Marine observers will have at least one set of binoculars available for each person to aid in the detection of marine mammals.
- Marine observers will scan the water from the ship to the horizon and be responsible for all observations in their sector. In searching the assigned sector, the lookout will always start at the forward part of the sector and search aft (toward the back). To search and scan, the lookout will hold the binoculars steady so the horizon is in the top third of the field of vision and direct the eyes just below the horizon. The lookout will scan for approximately five seconds in as many small steps as possible across the field seen through the binoculars. They will search the entire sector in approximately five-degree steps, pausing between steps for approximately five seconds to scan the field of view. At the end of the sector search, the glasses will be lowered to allow the eyes to rest for a few seconds, and then the lookout will search back across the sector with the naked eye.
- Observers will be responsible for informing the Test Director of any marine mammal or sea turtle that may need to be avoided, as warranted.

11.3.2.3 Operating Procedures

Section 11.4 presents detailed information on clearance procedures. The following gives a general overview of the requirements of monitoring during RDT&E activities that involve sonar.

- Test Directors will, as appropriate to the event, make use of marine species detection cues and information to limit interaction with marine species to the maximum extent possible, consistent with the safety of the ship.
- During operations involving mid-frequency active (MFA) sonar, personnel will use all available sensor and optical systems (such as night vision goggles to aid in the detection of marine mammals).
- Navy aircraft participating will conduct and maintain, when operationally feasible, required, and safe, surveillance for marine species of concern as long as it does not violate safety constraints or interfere with the accomplishment of primary operational duties.

- Marine mammal detections by aircraft will be immediately reported to the Test Director. This action will occur when it is reasonable to conclude that the course of the ship will likely close the distance between the ship and the detected marine mammal.
- For tests that require the use of safety zones, when marine mammals are detected by any means (aircraft, shipboard lookout, or acoustically) within 914 m (1,000 yd) of the sonar system, the platform will limit active transmission levels to at least 6 decibels (dB) below normal operating levels.
- Vessels will continue to limit maximum transmission levels by this 6-dB factor until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 914 m (1,000 yd) beyond the location of the last detection.
- Should a marine mammal be detected within or closing to inside 457 m (500 yd) of the sonar dome, active sonar transmissions will be limited to at least 10 dB below the equipment's normal operating level. Platforms will continue to limit maximum ping levels by this 10-dB factor until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 914 m (1,000 yd) beyond the location of the last detection.
- Should the marine mammal be detected within or closing to inside 183 m (200 yd) of the sonar dome, active sonar transmissions will cease. Sonar will not resume until the animal has been seen to leave the area, has not been detected for 30 minutes, or the vessel has transited more than 914 m (1,000 yd) beyond the location of the last detection.
- If the need for power-down should arise, as detailed in "Safety zones" item above, Navy staff will follow the requirements as though they were operating at 235 dB, the normal operating level (i.e., the first power-down will be to 229 dB, regardless of the level above 235 dB the sonar was being operated).
- Prior to start up or restart of active sonar, operators will check that the safety zone radius around the sound system is clear of marine mammals.
- Sonar levels (generally) – the Navy will operate sonar at the lowest practicable level, not to exceed 235 dB, except as required to meet RDT&E objectives.
- Helicopters will observe/survey the vicinity of an NSWC PCD RDT&E activity for 10 minutes before the first deployment of active (dipping) sonar in the water.
- Helicopters will not dip their sonar within 183 m (200 yd) of a marine mammal and will cease pinging if a marine mammal closes within 183 m (200 yd) after pinging has begun.

11.3.2.4 Special Conditions Applicable for Bow-Riding Dolphins

If, after conducting an initial maneuver to avoid close quarters with dolphins, the ship concludes that dolphins are deliberately closing in on the ship to ride the vessel's bow wave, no further mitigation actions will be necessary because dolphins are out of the main transmission axis of the active sonar while in the shallow-wave area of the vessel bow.

11.3.2.5 Monitoring

The U.S. Navy is committed to demonstrating environmental stewardship while executing its National Defense mission and is responsible for compliance with a suite of Federal environmental and natural resources laws and regulations that apply to the marine environment. As part of those responsibilities, an assessment of the long-term and/or population-level effects of NSWC PCD RDT&E activities as well as the efficacy of mitigation measures is necessary. The Navy is developing an Integrated Comprehensive Monitoring Program (ICMP) for marine species to assess the effects of NSWC PCD RDT&E activities on marine species and investigate population trends in marine species distribution and abundance in locations where NSWC PCD RDT&E activities regularly occurs.

The primary goals of the ICMP for NSWC PCD RDT&E activities are:

- To monitor Navy RDT&E exercises for compliance with the terms and conditions of the Endangered Species Act (ESA) Biological Opinion and MMPA authorization.
- Estimate the number of individuals (primarily marine mammals) exposed to sound levels above current regulatory thresholds.
- Assess the effectiveness of the Navy's marine species mitigation.
- To minimize exposure of protected species (primarily marine mammals) to sound levels from active sonar or sound pressure levels from underwater detonations currently considered to result in harassment.
- To document trends in species distribution and abundance in the NSWC PCD Study Area.
- To add to the knowledge base on potential behavioral and physiological effects to marine species from active sonar and underwater detonations.
- To assess the practicality and usefulness of a number of mitigation tools and techniques.

By using a combination of monitoring techniques or tools appropriate for the species of concern, type of Navy activities conducted in the area, sea state conditions, and the size of the operating area (OPAREA), the detection, localization, and observation of marine species can be maximized. This ICMP will evaluate the range of potential monitoring techniques that can be tailored to any NSWC PCD RDT&E activity and the appropriate species of concern. Further refinement of the ICMP will occur through the ERP desk.

11.3.2.6 Strikes Between Marine Mammals and Surface Vessels will be Avoided.

Ship strikes can be prevented by maneuvering to avoid collision when a marine mammal is sighted. Maintaining alert vessel lookouts when traveling at high speeds is recommended to reduce the potential for a collision to occur with a marine mammal.

11.3.2.7 Potential Protective Measures

The Navy is actively engaged in acoustic monitoring research involving a variety of methodologies (e.g., underwater gliders); to date, none of the methodologies have been developed to the point where they could be used as an actual mitigation tool. The Navy will continue to coordinate passive detection research specific to the proposed use of active sonar. As technology and methodologies become available, the applicability and viability of active sonar will be evaluated for incorporation into this mitigation plan.

11.3.2.8 Long-Term Passive Acoustic Monitoring

The Navy has sponsored several workshops to evaluate the current state of knowledge and potential for future acoustic monitoring of marine mammals on instrumented ranges. The workshops brought together acoustic experts and marine biologists from the Navy and other research organizations to present data and information on current acoustic monitoring research efforts and to evaluate the potential for incorporating similar technology and methods on instrumented ranges. However, acoustic detection, identification, localization, and tracking of individual animals still requires a significant amount of research effort to be considered a reliable method for marine mammal monitoring. The Navy supports research efforts on acoustic monitoring for instrumented ranges and will continue to investigate the feasibility of passive acoustics as a potential mitigation and monitoring tool.

11.3.2.9 Coordination and Reporting

The Navy will coordinate with NMFS Stranding Coordinators for any unusual marine mammal behavior. This includes any stranding, beached live/dead, or floating marine mammals that may occur coincidentally with Navy RDT&E activities.

The MFA sonar mitigation measures, in particular, have been developed in full consideration of the recommendations of the joint National Oceanic and Atmospheric Administration / Navy report on the Bahamas marine mammal stranding event (Department of Commerce and Department of the Navy [DON], 2001).

11.4 PROTECTIVE MEASURES RELATED TO DETONATIONS AND PROJECTILES

- No detonations over 34 kilograms (kg) (75 pounds [lb]) will be conducted in territorial waters. This does not apply to the line charge detonation, which is a 107 m (350 ft) detonation cord with explosives lined from one end to the other end in 2 kg (5 lb) increments and total 794 kg (1,750 lb) of NEW. This charge is considered one explosive source that has multiple increments that detonate at one time.
- The number of live mine detonations will be minimized and the smallest amount of explosive material possible to achieve test objectives will be used.
- Activities will be coordinated through the Environmental Help Desk to allow potential concentrations of detonations in a particular area over a short time to be identified and avoided.
- Visual surveys and aerial surveys will be conducted for all test operations that involve detonation events with large net explosive weight (NEW). Any protected species sighted will be avoided.
- Line charge tests would not be conducted during the nighttime.

- Mitigations will be determined through the ERP review based on test activities including the size of detonations, test platforms, and environmental effects documented in this EIS/OEIS. Clearance zones will be determined based on the environmental criteria and explosive safety guidance (DON, 2007). The most conservative requirements in comparing the criteria with the guidance will be used.

11.5 CLEARANCE PROCEDURES

Visual surveys will be conducted from vessels and/or aircraft, when the environmental review process (ERP) desk determines that they are required. Aerial surveys will be used for detonations involving large amounts of the NEW, since the impact range could be too large to be effectively surveyed from a surface vessel only. The ERP desk will evaluate the proposed type of test activities and determine the appropriate monitoring requirements including pre- and post-monitoring times, number of observers, and any other specifics for the required mitigation activities.

A visual survey will consist of searching the water 360 degrees around the detonation point and out to the Level B behavioral harassment zone for the presence or indicators of protected species. If a protected species is sighted within 914 m (3,000 ft) of the detonation point all efforts will be made to avoid these sighted species. Since the effectiveness of visual surveys depends on not only on observer training and experience, but also on sea state and observer fatigue, operations requiring visual surveys will be carried out only in sea states of 3.5 or lower as described in Table 11-1. Higher winds typically increase wave height and create “white cap” conditions, thus limiting an observer’s ability to locate surfacing marine mammals and sea turtles. The ERP personnel will also provide suggestions based on the hours of operation, the type of RDT&E activity, and the level of mitigation requirements to reduce observer fatigue.

When the test platform (surface vessel or aircraft) arrives at the test site, an initial evaluation of environmental suitability will be made. This evaluation will include an assessment of sea state and verification that the area is clear of visually detectable marine mammals, sea turtles, and indicators of their presence. Large *Sargassum* rafts and large concentrations of jellyfish are considered indicators of potential sea turtle presence. Large flocks of birds and large schools of fish are considered indicators of potential marine mammal presence.

Table 11-1. Pierson - Moskowitz Sea Spectrum - Sea State Scale for Marine Mammal and Sea Turtle Observation

Wind Speed (Kts)	Sea State	Significant Wave (m) (Ft)	Significant Range of Periods (Sec)	Average Period (Sec)	Average Length of Waves (m) (Ft)
3	0	< 0.15 (<0.5)	<0.5 - 1	0.5	0.46 (1.5)
4	0	< 0.15 (<0.5)	0.5 - 1	1	0.61 (2)
5	1	0.15 (0.5)	1 - 2.5	1.5	2.90 (9.5)
7	1	0.30 (1)	1 - 3.5	2	3.96 (13)
8	1	0.30 (1)	1 - 4	2	4.88 (16)
9	2	0.46 (1.5)	1.5 - 4	2.5	6.10 (20)
10	2	0.61 (2)	1.5 - 5	3	7.92 (26)

Table 11-1. Pierson - Moskowitz Sea Spectrum - Sea State Scale for Marine Mammal and Sea Turtle Observation (Cont'd)

Wind Speed (Kts)	Sea State	Significant Wave (m) (Ft)	Significant Range of Periods (Sec)	Average Period (Sec)	Average Length of Waves (m) (Ft)
11	2.5	0.76 (2.5)	1.5 - 5.5	3	10.06 (33)
13	2.5	0.91 (3)	2 - 6	3.5	12.04 (39.5)
14	3	1.07 (3.5)	2 - 6.5	3.5	14.02 (46)
15	3	1.22 (4)	2 - 7	4	16.0 (52.5)
16	3.5	1.37 (4.5)	2.5 - 7	4	17.98 (59)
17	3.5	1.52 (5)	2.5 - 7.5	4.5	19.96 (65.5)
18	4	1.83 (6)	2.5 - 8.5	5	24.08 (79)
19	4	2.13 (7)	3 - 9	5	28.04 (92)
20	4	2.29 (7.5)	3 - 9.5	5.5	30.18 (99)
21	5	2.43 (8)	3 - 10	5.5	32.0 (105)

m = Meters; Ft = Feet; Kts = Knots; Sec = Seconds

If the initial evaluation indicates that the area is clear, visual surveying will begin. The area around the center of the noise source, with a radius equal to 914 m (3,000 ft) (Level B behavioral harassment zone), will be visually surveyed for the presence of protected species and protected species indicators. Visual surveys will be conducted from the test platform before test activities begin. If the platform is a surface vessel, no additional aerial surveys will be required except for events involving large detonations. For surveys requiring only surface vessels, aerial surveys may be opportunistically conducted by aircraft participating in the test. If surface vessels were participating in activities with large detonations, shipboard surveys on these vessels will be required as well.

Shipboard monitoring will be staged from the highest point possible on the vessel. The observer(s) will be experienced in shipboard surveys, familiar with the marine life of the area, and equipped with binoculars of sufficient magnification. Each observer will be provided with a two-way radio that will be dedicated to the survey, and will have direct radio contact with the Test Director. Observers will report to the Test Director any sightings of marine mammals, sea turtles, or indicators of these species, as described previously. Distance and bearing will be provided when available. Observers may recommend a "Go"/"No Go" decision, but the final decision will be the responsibility of the Test Director.

If one or more aircraft participate in visual surveys, the area to be surveyed will extend from the noise source out to at least 914 m (3,000 ft). The pilots will employ standard flight patterns. In addition to the previous requirements for boat-based observers, aerial observers will be experienced in aerial surveys. If operational constraints permit, it will be preferable that aerial surveys be conducted at an altitude of 152 to 229 m (about 500 to 750 ft). Each observer will have direct radio contact with the Test Director. Observers will report to the Test Director any sightings of marine mammals, sea turtles, or indicators of these species, as described previously. Distance and bearing will be provided when available. Observers may recommend a "Go"/"No Go" decision, but the final decision will be the responsibility of the Test Director.

The mission will be postponed if any marine mammal, sea turtle, *Sargassum* raft, jellyfish concentration, large flock of birds, or large school of fish were visually detected within 914 m (3,000 ft) of the detonation point. The delay will continue until the animal or animal indicator has voluntarily moved or drifted out of the impact range (i.e., greater than 914 m [3,000 ft] from the detonation point). At that point, visual surveys will be restarted before test activities begin.

Post-mission surveys will be conducted from the surface vessel(s) and aircraft used for pre-test surveys. Observation of the impact range will be carried out to verify the presence of dead or injured marine mammals or sea turtles. Any such affected marine species will be documented and reported to NMFS. The report will include the date, time, location, test activities, species (to the lowest taxonomic level possible), behavior, and number of animals.

This page is intentionally blank.

12. MONITORING AND REPORTING

Test plans for individual events conducted at Naval Surface Warfare Center Panama City Division (NSWC PCD) and covered by this Letter of Authorization (LOA) would include required mitigation measures including monitoring and reporting. NSWC PCD would disseminate this information prior to each operation to the appropriate Navy test director or point of contact. Systematic monitoring of the affected area for marine mammals will be conducted prior to, during, and after test events using aerial and/or ship-based visual surveys dependent on the characteristics of the noise source, the operational components of the test event, and the potential for “take” to occur to protected species. Observers will record information during the test activity. Data recorded will include exercise information (time, date, and location) and marine mammal and/or indicator presence. Personnel will immediately report observed stranded or injured marine mammals to the National Marine Fisheries Service (NMFS) stranding response network and NMFS Regional Office.

This page is intentionally blank.

13. RESEARCH

The Navy provides a significant amount of funding and support to marine research. The agency provides nearly $10 million annually to universities, research institutions, federal laboratories, private companies, and independent researchers around the world to study marine mammals. The Navy sponsors 70 percent of all U.S. research concerning the effects of human-generated sound on marine mammals and 50 percent of such research conducted worldwide. Major topics of Navy-supported research include:

- Better understanding of marine species distribution and important habitat areas.
- Developing methods to detect and monitor marine species before and during training.
- Understanding the effects of sound on marine mammals, sea turtles, fish, and birds.
- Developing tools to model and estimate potential effects of sound.

This research is directly applicable to the Naval Surface Warfare Center Panama City Division (NSWC PCD) Study Area, particularly with respect to the investigations of the potential effects of underwater noise sources on marine mammals and other protected species. NSWC PCD employs sonar and underwater explosives, which introduce sound into the marine environment. The Marine Life Sciences Division of the Office of Naval Research (ONR) currently coordinates six programs that examine the marine environment and are devoted solely to studying the impact of noise and/or the implementation of technology tools that will assist the Navy in studying and tracking marine mammals. The six programs are:

1. Environmental Consequences of Underwater Sound (ECOUS)
2. Non-Auditory Biological Effects of Sound on Marine Mammals
3. Effects of Sound on the Marine Environment (ESME)
4. Sensors and Models for Marine Environmental Monitoring
5. Effects of Sound on Hearing of Marine Animals
6. Passive Acoustic Detection, Classification, and Tracking of Marine Mammals

The Navy has also developed the technical reports referenced within this document, which include the Marine Resource Assessments (MRAs) and the marine mammal density reports. Furthermore, research cruises conducted by the National Marine Fisheries Service (NMFS) and by academic institutions in the Gulf of Mexico (GOM) have received funding from the U.S. Navy. For instance, the ONR contributed financially to the Sperm Whale Seismic Survey (SWSS) coordinated by Texas A&M University. The goals of the SWSS are to examine effects of the oil and gas industry on sperm whales and what mitigations would be employed to minimize adverse effects to the species. All of this research helps the NSWC PCD to understand the marine environment in which they operate and the effects that may arise from the use of underwater noise in the GOM.

The Navy will continue to fund ongoing marine mammal research, and plans to coordinate long-term monitoring/studies of marine mammals on various established ranges and operating areas. The Navy will continue to research and contribute to university/external research to improve the state of the science regarding marine species biology and acoustic effects. These efforts include mitigation and monitoring programs; data sharing with NMFS and via the literature for research and development efforts; and future research as described previously.

14. LIST OF PREPARERS

This Letter of Authorization (LOA) was prepared for the U.S. Navy by Science Applications International Corporation (SAIC). A list of key preparation and review personnel is included.

The Navy Technical Representative for this document is:

Carmen Ferrer, Environmental Planner
Naval Surface Warfare Center Panama City Division
Code XPF1
110 Vernon Avenue
Panama City, FL 32407 7001
Telephone (850) 234-4146

Key personnel included the following:

NAVAL SURFACE WARFARE CENTER PANAMA CITY DIVISION

Name/Title	Project Role	Subject Area	Qualifications
Elizabeth Branham Oceanographer/Test and Evaluation Division Coordination	Navy Technical Reviewer		18 years Navy experience

SCIENCE APPLICATIONS INTERNATIONAL CORPORATION (SAIC)
1140 Eglin Parkway
Shalimar, FL 32579

Name	Subject Area	Years of Experience
Hilary Brich M.A. Philosophy B.S. Philosophy	Technical Editor	13 years experience
Janet Clarke M.A. Anthropology B.S. Wildlife Management	Marine Mammal Density Analysis	25 years environmental science
Christopher Grow Environmental Scientist	Internal Comment Incorporation	1 year environmental science
Sarah Hagedorn Environmental NEPA Scientist M. Environmental Management B.S. Biology	Author	5 years environmental science
Joel Hibbard M.S. Mathematics B.S. Mathematics	Underwater Noise Analyst	6 years acoustics experience
Jennifer N. Latusek Environmental Scientist M. Environmental Management B.S. Marine Biology	Deputy Project Manager Author/Technical Reviewer	6 years environmental science

List of Preparers

Name	Subject Area	Years of Experience
W. James McKee Environmental Scientist B.S. Marine Biology	Author/Technical Reviewer	22 years environmental science
Dennis Peters Environmental Scientist M. S. Bio-Environmental Oceanography B. S. Biology	Program Manager	24 years environmental science
Russ Piovesan Environmental Scientist M.S. Environmental Management B.S. Biology	Project Manager	10 years environmental science
Angela Toole Technical Editor B.A. Journalism/Advertising	Technical Editor	25 years editing experience
Bill Renner M.S. Mathematics	Underwater Noise Analyst	29 years acoustics experience
Andy Rogers Environmental Scientist Ph.D. Marine Estuarine Environmental Science M.S. Marine Estuarine Environmental Science B.A. Speech	Comment Incorporation	10 years supporting Navy environmental and safety documentation

15. REFERENCES

Advisory Committee on Acoustic Impacts on Marine Mammals, 2006. Report to the U.S. Marine Mammal Commission. Marine Mammal Commission; Bethesda, Maryland.

Au, W.W.L., Pack, A.A., Lammers, M.O., Herman, L.M., Deakos, M. and Andrews, K., 2006. "Acoustic properties of humpback whale song." Journal of the Acoustical Society of America, 120:1103-1110.

Baird, R. W., D. L. Webster, D. J. McSweeney, A. D. Ligon, G. S. Schorr, and J. Barlow, 2006. Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawai'i. *Canadian Journal of* Zoology, Vol 84, pp 1120–1128.

Barlow, J. and R. Gisiner, 2006. Mitigating, monitoring, and assessing the effects of anthropogenic sound on beaked whales. *Journal of Cetacean Research and Management.* 7(3):239-249.

Biassoni, N., P. J. Miller, and P. L. Tyack., 2000. Preliminary results of the effects of SURTASS-LFA sonar on singing humpback whales. Woods Hole Oceanographic Institute, Technical Report No. 2000-06. Woods Hole, Massachusetts.

Bjørge, A., 2002. How persistent are marine mammal habitats in an ocean of variability? Pages 63-91 in P.G.H. Evans and J.A. Raga, eds. Marine mammals: Biology and conservation. New York: Kluwer Academic/Plenum Publishers.

Bradshaw, C. J., K. Evans, and M. A. Hindell, 2006. "Mass cetacean strandings-a plea for empiricism," Conservation Biology 20, 584-586.

Carretta, J.V., K. A. Forney, M. M. Muto, J. Barlow, J. Baker, B. Hanson, and M.S. Lowry, 2007. U.S. Pacific Marine Mammal Stock Assessments: 2006. NOAA Technical Memorandum: NOAA-TM-NMFS-SWFSC-398. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service.

Centers for Disease Control and Prevention (CDC), 2003. Sixteenth Meeting of the Advisory Board on Radiation and Worker Health May 19-20, 2003. Oak Ridge, Tennessee.

Corkeron, P.J., and R.C. Connor, 1999. Why do baleen whales migrate? Marine Mammal Science 15(4):1228-1245.

Cox, T. M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Ranford, L. Crum, A. D'amico, G. D'spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P. D. Jepson, D. Ketten, C. D. Macleod, P. Miller, S. Moore, D. C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Meads, L. Benner, 2006. Understanding the impacts of anthropogenic sound on beaked whales. *Journal of Cetacean Research Management*, Vol 7, pp 177–187.

Croll, D. A., C. W. Clark, J. Calambokidis, W. T. Ellison, and B. R. Tershy, 2001. Effects of anthropogenic low-frequency noise on the foraging ecology of Balaenoptera whales. Animal Conservation 4:13-27

Crum, L.A., and Y. Mao, 1996. "Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety." *Journal of the Acoustical Society of America* 99:2898-2907.

Culik, B. M., 2002. "Review on Small Cetaceans: Distribution, Behaviour, Migration and Threats," in United Nations Environment Programme, Convention on Migratory Species (Marine Mammal Action Plan/Regional Seas Reports and Studies No. 177), p. 343.

Culik, B. M., S. Koschinski, N. Tregenza, and G.M. Ellis, 2001. Reactions of harbour porpoises (*Phocoena phocoena*) and herring (*Clupea harengus*) to acoustic alarms. *Marine Ecology Progress Series*, Vol 211, pp

255–260.Dalecki, D., S. Z. Child, and C. H. Raeman, 2002. Lung damage from exposure to low-frequency underwater sound. *Journal of the Acoustical Society of America*, Vol 111, pp 2462A.

D'Amico, A., and W. Verboom, 1998. "Report of the Bioacoustics Panel, NATO/SACLANT," pp. 2-1-2-60.

D'Spain, G. L., A. D'Amico, and D.M. Fromm., 2006. Properties of the underwater sound fields during some well documented beaked whale mass stranding events. Journal of Cetacean Research and Management 7(3):223-238.

Dalecki, D., S. Z. Child, and C. H. Raeman, 2002. Lung damage from exposure to low-frequency underwater sound. *Journal of the Acoustical Society of America*, Vol 111, pp 2462A.

Department of Commerce and Department of the Navy (DON), 2001. *Joint Interim Report*, *Bahamas Marine Mammal Stranding Activity of 15–16 March 2000*. December 2001.

Department of the Navy (DON), (1998), "Final Environmental Impact Statement, Shock Testing the SEAWOLF Submarine," U.S. Department of the Navy, Southern Division, Naval Facilities Engineering Command, North Charleston, SC, 637 p.

————, 2001. Department of the Navy, Chief of Naval Operations, "Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar," January 2001.

————, 2001. Environmental Impact Statement for the Shock Trial of the *WINSTON S. CHURCHILL*, (DDG83). February 2001.

————, 2001a. Office of Naval Research, "Final Environmental Impact Statement for the North Pacific Acoustic Laboratory (NPAL)," Volumes I and II, January 2001.

————, 2003. Department of the Navy, Commander U.S. Pacific Fleet. "Report on the results of the inquiry into allegations of marine mammal impacts surrounding the use of active sonar by USS SHOUP (DDG 86) in the Haro Strait on or about 5 May 2003," 9 February 2003*. (***** ERROR: correct date of issue was 9 Feb 04).

————, 2005. Draft Overseas Environmental Impact Statement/Environmental Impact Statement for Undersea Warfare Training Range. Department of the Navy. October 2005.

————, 2005a. Undersea Warfare Exercise (USWEX) Programmatic Environmental Assessment/Overseas Environmental Assessment. United States Pacific Fleet.

————, 2006. Mid-Frequency Active Sonar Effects Analysis Interim Policy. Office of the Chief of Naval Operations. Washington, DC. March 6, 2006.

————, 2006a. 2006 Supplement to the 2002 Rim of the Pacific (RIMPAC) Programmatic Environmental Assessment. Third Fleet. May 2006.

————, 2007. Marine Resources Assessment for the Gulf of Mexico. Prepared for the Department of the Navy, U.S. Fleet Forces Command, Norfolk, Virginia. Contract #N62470-02-D-9997, CTO 0030. Prepared by Geo-Marine, Inc., Hampton, Virginia.

————, 2007a. Undersea Warfare Exercise (USWEX) Programmatic Environmental Assessment/Overseas Environmental Assessment. United States Pacific Fleet.

————, 2007b. Final Supplement to the Final Comprehensive Overseas Environmental Assessment for Major Atlantic Fleet Training Exercises. United States Fleet Forces Command. May 2007.

————, 2007c. Hawaii Range Complex Draft Environmental Impact Statement/Overseas Environmental Impact Statement. United States Pacific Fleet. August 2007.

————, 2007d. Final Comprehensive Report for the Operation of the Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar Onboard the R/V Cory Chouest and USNS IMPECCABLE (T-AGOS 23) Under the National Marine Fisheries Service Regulations 50 CFR 216 Subpart Q. National Marine Fisheries Service (NMFS)/National Oceanic and Atmospheric Administration (NOAA).

————, 2007. Department of the Navy, Chief of Naval Operations, "Final Supplemental Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar," April 2007.

Dierauf, L. A., and F. M. D. Gulland, 2001. "Marine Mammal Unusual Mortality Events," in Marine Mammal Medicine, edited by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton), pp. 69-81.

Dison, W. J. and F. J. Massey, Jr., (1969). Introduction to statistical analysis. Madgraw-Hill, Inc. NY.

Dobson, A.J., 2002. *An introduction to generalized linear models*. Second Edition. Chapman and Hall, CRC Press, Boca Raton, Florida.

Dorne, J.L.C.M., K. Walton, and A.G. Renwick, 2005. "Human variability in xenobiotic metabolism and pathway-related uncertainty factors for chemical risk assessment: a review," Food and Chemical Toxicology, 43(2):203-216.

EPA (Environmental Protection Agency), 1998. Guidelines for ecological risk assessment. Federal Register 63:26846 – 26924; OSHA occupational noise regulations at 29 CFR 1910.95.

Evans, D.L., and G.R. England, 2001. "Joint Interim Report Bahamas Marine Mammal Stranding Event of 15-16 March 2000," (Department of Commerce), pp. 1-66.

Evans, G. H., and L. A. Miller, 2004. Proceedings of the Workshop on Active Sonar and Cetaceans. *European Cetacean Society Newsletter,* No. 42 Special Issue – February 2004.

Fahlman, A., A. Olszowka, B. Bostrom, and D. R. Jones, 2006. Deep diving mammals: dive behavior and circulatory adjustments contribute to bends avoidance. *Respiratory Physiology & Neurobiology* 153:66-77.

Feller, W., 1968. Introduction to probability theory and its application. Vol. 1. 3rd ed. John Wilay & Sons, NY, NY.

Fernández, A., J. Edwards, V. Martín, F. Rodríguez, A. Espinosa de los Monteros, P. Herráez, P. Castro, J. R. Jaber, and M. Arbelo, 2005. ""Gas and fat embolic syndrome" involving a mass stranding of beaked whales exposed to anthropogenic sonar signals," Journal of Veterinary Pathology 42, 446-457.

Fiedler, P.C., 2002. Ocean environment. Pages 824-830 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Finneran, J. J., and C. E. Schlundt, 2004. *Effects of Intense Pure Tones on the Behavior of Trained Odontocetes.* SPAWAR Systems Center, San Diego, California. September 2003.

Finneran, J. J., C. E. Schlundt, D. A. Carder, J. A. Clark, J. A. Young, J. B. Gaspin, and S. H. Ridgway, 2000. Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and a beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions. *Journal of the Acoustical Society of America*, Vol 108, No 1, pp 417–431.

Finneran, J. J., D. A. Carder, and S. H. Ridgway, 2001. Temporary threshold shift (TTS) in bottlenose dolphins (*Tursiops truncatus*) exposed to tonal signals. 142nd Meeting of the Acoustical Society of America, Fort Lauderdale, Florida, December 2001. *Journal of the Acoustical Society of America*, Vol 110, No 5, p 2749(A).

————, 2002. Temporary shift in masked hearing thresholds in odontocetes after exposure to single underwater impulses from a seismic watergun. *Journal of the Acoustical Society of America*, Vol 111, No 6, pp 2929–2940.

————, 2003. Temporary threshold shift (TTS) measurements in bottlenose dolphins (*Tursiops truncatus*), belugas (*Delphinapterus leucas*), and California sea lions (*Zalophus californianus*). Environmental Consequences of Underwater Sound (ECOUS) Symposium, San Antonio, Texas. 12–16 May 2003.

————, 2005. Temporary threshold shift in bottlenose dolphins (*Tursiops truncatus*) exposed to mid-frequency tones. *Journal of the Acoustical Society of America*, Vol 118, pp 2696–2705.

Florida Fish and Wildlife Conservation Commission (FWC), 2007. Marine Mammal Pathobiology Laboratory Manatee Mortality-Database Search Results. Retrieved from http://www.floridamarine.org/manatees/search_individual.asp, on 28 March 2007.

————, 2007b. Manatee Mortality—Database Search. Accessed online May 2007 at: http://research.myfwc.com/manatees/search_summary.asp.

Food and Drug Administration, U.S. Department of Agriculture, and Centers for Disease Control and Prevention, 2001. Draft assessment of the relative risk to public health from foodborne Listeria monocytogenes among selected categories of ready-to-eat foods. Food and Drug Administration, Center for Food Safety and Applied Nutrition; U.S. Department of Agriculture, Food Safety and Inspection Service; and Centers for Disease Control and Prevention. Rockville, Maryland and Washington, D.C.

Forcada, J., 2002. Distribution. Pages 327-333 in W.F. Perrin, B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego: Academic Press.

Frantzis, A., (1998). “Does acoustic testing strand whales?,” in Nature, p. 29.

Freitas, L., 2004. “The stranding of three Cuvier’s beaked whales Ziphius cavirostris in Madeira Archipelago - May 2000,” in European Cetacean Society 17th Annual Conference (Las Palmas, Gran Canaria).

Fromm, D., 2004a. "Acoustic Modeling Results of the Haro Strait For 5 May 2003." Naval Research Laboratory Report, Office of Naval Research, 30 January 2004.

Fromm, D., 2004b. “EEEL Analysis of Shoup Transmissions in the Haro Strait on 5 May 2003,” Naval Research Laboratory briefing of 2 September 2004.

Geraci, J.R., and V.J. Lounsbury, 2005. Marine Mammals Ashore: A Field Guide fo Strandings. Second Edition. National Aquarium in Baltimore, Baltimore, MD. 371 pp.

Geraci et al.; in V. L. Trainer and D. G. Baden, 1999. High affinity binding of red tide neurotoxins to marine mammal brain. *Aquatic Toxicology*, Vol 46, pp 139–148.

Goertner, J. F., 1982. *Prediction of Underwater Explosion Safe Ranges for Sea Mammals*. Research and Technology Department, Naval Surface Weapons Center, Dahlgren, VA and Silver Spring, Maryland. NSWC TR 82-188.

Griffin, R. B., 1999. Sperm whale distributions and community ecology associated with a warm-core ring off Georges Bank. Marine Mammal Science 15(1):33-51.

Gulland, F. M. D., 2006. “Review of the Marine Mammal Unusual Mortality Event Response Program of the National Marine Fisheries Service,” (Report to the Office of Protected Resources, NOAA/National Marine Fisheries Service, Silver Springs, MD), p. 32.

Gulland, F. M. D., and A. J. Hall, 2005. “The Role of Infectious Disease in Influencing Status and Trends,” in Marine Mammal Research, edited by J. E. Reynolds, W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen (John Hopkins University Press, Baltimore), pp. 47-61.

References

Hain, J. H., and R. D. Kenney, 2005. *A Review and Update to the Technical Report of December 2002 for the Estimation of Marine Mammal and Sea Turtle Densities in the Cherry Point Operating Area Specific to the Distribution and Densities of Right Whales*. 28 June 2005.

Harwood, J., 2002. "Mass Die-offs," in Encyclopedia of Marine Mammals, edited by W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Academic Press, San Diego), pp. 724-726.

Haubold, E. M., C. Deutsch, and C. Fonnesbeck, 2006. *Final Biological Status Review of the Florida Manatee (*Trichechus manatus latirostris*)*. Status Assessment by the 2005-2006 Florida Manatee Biological Review Panel. Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute: St. Petersburg, Florida. 133 pp.

Hennessy, M. B., J. P. Heybach, J. Vernikos, AND S. Levine, 1979. Plasma corticosterone concentrations sensitively reflect levels of stimulus intensity in the rat. Physiology and Behavior 22:821–825.

Hoelzel, A. R., 2003. Marine Mammal Biology: An Evolutionary Approach (Blackwell Publishing, Malden MA).

Hohn, A.A., D.S. Rotstein, C.A. Harms, and B.L. Southall. 2006. Report on marine mammal unusual mortality event UMESE0501Sp: Multispecies mass stranding of pilot whales (*Globicephala macrorhynchus*), minke whale (*Balaenoptera acutorostrata*), and dwarf sperm whales (*Kogia sima*) in North Carolina on 15-16 January 2005. NOAA Technical Memorandum NMFS-SEFSC-537:1-222.

Hoffman, J. P., 2004. *Generalized linear models. An applied approach*. Pearson Education, Inc., Boston, Massachusetts.

Houser, D.S., D. A. Helweg, and P. W. B. Moore, 2001. A bandpass filter-bank model of auditory sensitivity in the humpback whale. *Aquatic Mammals* Vol 27,pp 82–91.

ICES, 2005a. Report of the Ad-hoc Group on the Impacts of Sonar on Cetaceans and Fish- 2nd edition. International Council for the Exploration of the Sea. ICES AGISC CM 2005/ACE:06. 25 pp.

ICES, 2005b. Answer to DG Environment request on scientific information concerning impact of sonar activities on cetacean populations. International Council for the Exploration of the Sea. 5 pp.

Jansen, G., 1998. "Physiological effects of noise," In *Handbook of Acoustical Measurements and Noise Control, 3rd Edition*, New York: Acoustical Society of America.

Jepson, P. D., M. Arbelo, R. Deaville, I. A. P. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herráez, A. M. Pocknell, F. Rodríguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and A. Fernández, 2003. Gas-bubble lesions in stranded cetaceans. *Nature*, Vol 425, pp 575.

Jochens, A., D. Biggs, D. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, J. Wormuth, and B. Würsig, 2006. Sperm whale seismic study in the Gulf of Mexico, Summary Report, 2002-2004. OCS Study MMS 2006-034. New Orleans, Louisiana: Minerals Management Service.

Johnston, D. W., 2000. The effect of acoustic harassment devices on harbor porpoises (Phocoena phocoena) in the Bay of Fundy, Canada. Biological Conservation 108: 113-118.

Kastak, D., and R. J. Schusterman, 1996. "Temporary threshold shift in a harbor seal (Phoca vitulina)," Journal of the Acoustical Society of America, 100(3):1905-1908.

Kastak, D., R. J. Schusterman, B. L. Southall, and C. J. Reichmuth, 1999. Underwater temporary threshold shift induced by octave-band noise in three species of pinniped. *Journal of the Acoustical Society of America*, Vol 106, No 2, pp 1142–1148.

References

Kastak D., B. L. Southall, R. J. Schusterman, and C. R. Kastak, 2005. “Underwater temporary threshold shift in pinnipeds: Effects of noise level and duration,” *Journal of the Acoustical Society of America*, 118:3154–3163.

Kastelein, R. A., Rippe, H. T., Vaughan, N., Schooneman, N. M., Verboom, W. C., & de Haan, D., 2000. The effects of acoustic alarms on the behavior of harbor porpoises in a floating pen. Marine Mammal Science 16:46-64.

Kastelein, R. A., Verboom, W. C., Muijsers, M., Jennings, N. V., & van der Heul, S., 2005. The influence of acoustic emissions for underwater data transmission on the behaviour of harbor porpoises (Phocoena phocoena) in a floating pen. Marine Environmental Research 59:287-307.

Keeler, J. S., 1976. Models for noise-induced hearing loss. In: *Effects of Noise on Hearing*, ed. Henderson et al., 361–381. New York: Raven Press.

Ketten, D. R., 1997. Structure and Function in Whale Ears, *Bioacoustics*, vol.8, no. 1, pp. 103-136.

———, 1998. Marine mammal auditory systems: *A summary of audiometric and anatomical data and its implications for underwater acoustic impacts.* NOAA-TM-NMFSSWFSC-256, Department of Commerce.

———, 2005. Annex K: Report of the standing working group on environmental concerns. Appendix 4. Marine mammal auditory systems: a summary of audiometric and anatomical data and implications for underwater acoustic impacts. Journal of Cetacean Research and Management 7:286 - 289.

Knowlton, A. R., J. B. Ring, and B. Russell, 2002. Right Whale Sightings and Survey Effort in the Mid Atlantic Region: Migratory Corridor, Time Frame, and Proximity to Port Entrances. Report submitted to NMFS Ship Strike Working Group.

Kooyman, G. L., D. D. Hammond, and J. P. Schroeder, 1970. Brochograms and tracheograms of seals under pressure. *Science*, Vol 169, pp 82–84.

Krewski, D., C. Brown, and D. Murdoch, 1984. “Determining “safe” levels of exposure: safety factors or mathematical models?” *Toxicological Sciences*, 4:383-394.

Kryter K. D., W. D. Ward, J. D. Miller, and D. H. Eldredge, 1966. Hazardous exposure to intermittent and steady-state noise. *Journal of the Acoustical Society of America*, Vol 39, pp 451–464.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet, and M. Podesta, 2001. Collisions between ships and whales. Marine Mammal Science, Vol 17, No 1, pp 35–75.

Ljungblad, D. K., Wurig, B I., Swartz, S.L., & Keene, J.M. (1988). Observatons on the behavioral responses of bowhead whales (Balaena mysticetus) to active geophysical vessels in the Alaskan Beaufort Sea. Arctic, 41: 183-194.

Lowry, M. S., J. V. Carretta, K. A. Forney, M. M. Muto, J. Barlow, J. Baker, and B. Hanson, 2007. U.S. Pacific marine mammal stock assessments: 2006. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-SWFSC-398.

Malme, C. I., P. R. Miles, C. W. Clark, P. Tyack, and J. E. Bird, 1983. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior. BBN Rep. 5366. Rep. From Bolt Beranek and Newman, Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-174174.

———, 1984. Investigations of the potential effects of underwater noise from petroleum industry activities on migrating gray whale behavior/Phase II*:* January 1984 migration. BBN Rep. 5586. Rep. From Bolt Beranek and Newman, Inc., Cambridge, MA, for U.S. Minerals Manage. Serv., Anchorage, AK. Var. pag. NTIS PB86-218377.

———, 1985. Investigations of the potential effects of underwater noise from petroleum industry activities on feeding humpback whale behavior. Report No. 5851 prepared by bolt Beranek & Newman, Inc. for the U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska.

Malme, C. I., B. Wursig, J. E. Bird, and P. L. Tyack, 1986. Behavioral responses of gray whales to industrial noise: Feeding observations and predictive modeling, National Oceanic and Atmospheric Administration, Outer continental Shelf Environmental Assessment Program, Final Report of the Principal Investigators, Anchorage, Alaska: BBB Report No. 6265. OCS Study MMS 88-0048; NTIS PB88-249008.

Mate, B. M., S. L. Nieukirk, and S. D. Kraus, 1997. Satellite-monitored movements of the northern right whale. Journal of Wildlife Management 61:1393-1405.

Mazzuca, L., S. Atkinson, B. Keating, and E. Nitta, 1999. "Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998," Aquat. Mammals 25, 105-114.

McCauley, R. D., D. H. Cato, and A. F. Jeffery, 1996. A study of the impacts of vessel noise on humpback whales in Hervey Bay, Australia: Report prepared by the Department of marine Biology of the James Cook University for the Queenland Department of Environment and Heritage, Maryborough Office; Maryborough, Queensland, Australia.

McCauley, R. D., J. Fewtrell, A. J. Duncan, C. Jenner, M. N. Jenner, J. D. Penrose, R. I. T. Prince, A. Adhitya, J. Murdock, and K. McCabe, 2000a. Marine seismic surveys: analysis and propagation of air-gun signals; and effects of air-gun exposure on humpback whales, sea turtles, fishes and squid. Report R99-15 prepared for Australian Petroleum Production Exploration Association.

———, 2000b. Marine seismic surveys – a study of environmental implications. Australian Petroleum Production and Exploration Association Journal 2000: 692-708.

McCullagh, P., and J. A. Nedler, 1989. *Generalized linear models*. Second Edition. Chapman and Hall; London, United Kingdom.

McCulloch, C. E., and S. R. Searle, 2001. *Generalized, linear, and mixed models*. John Wiley and Sons, Inc.; New York, New York.

McEwen, Bruce S. and Wingfield, John C., 2003. The concept of allostasis in biology and biomedicine. Hormones and Behavior, 43, 2-15.

Mead, J. G., 2002. Beaked whales, overview. pp. 81-4. In: W.F. Perrin, B. Wursig and G.M. Thewissen (eds.) Encyclopedia of Marine Mammals. San Diego, California: Academic Press.

Miller, J. D., 1974. Effects of noise on people. *Journal of the Acoustical Society of America*, Vol 56, pp 729–764.

Miller, J. D., C. S. Watson, and W. P. Covell, 1963. Deafening effects of noise on the cat. *Acta Oto-Laryngologica* Supplement Vol 176, pp 1–91.

Mills, J. H., R. M. Gilbert, and W. Y. Adkins, 1979. "Temporary threshold shifts in humans exposed to octave bands of noise for 16 to 24 hours," Journal of the Acoustical Societyof America, 65:1238–1248.

Mullin, K. D. and G. L. Fulling, 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. *Marine Mammal Science* 20(4): 787-807.

Nachtigall, P. E., J. L. Pawloski, and W. W. L. Au, 2003a. "Temporary threshold shift and recovery following noise exposure in the Atlantic bottlenosed dolphin (*Tursiops truncates*)," *Journal of the Acoustical Society of America*, 113:3425-3429.

Nachtigall, P. E., A. Supin, J. L. Pawloski, and W. W. L. Au, 2004. "Temporary threshold shift after noise exposure in bottlenosed dolphin (*Tursiops truncates*) measured using evoked auditory potential," *Marine Mammal Science*, 20:673-687.

National Marine Fisheries Service (NMFS), 2003. *Environmental Assessment on the Effects of Scientific Research Activities Associated with Development of a Low-Power High-Frequency Sonar System to Detect Marine Mammals*. December 2003.

National Marine Fisheries Service (NMFS), 2005. Assessment of Acoustic Exposures on Marine Mammals in Conjunction with USS Shoup Active Sonar Transmissions in the Eastern Strait of Juan de Fuca and Haro Strait, National Marine Fisheries Service, Office of Protected Resources, Washington, 5 May 2003.

National Marine Fisheries Service (NMFS), 2005b. Recovery plan for the North Atlantic right whale (*Eubalaena glacialis*). Silver Spring, Maryland: National Marine Fisheries Service.

National Marine Fisheries Service (NMFS), 2007. FAQs about Marine Mammal Strandings. Retrieved from http://www.nmfs.noaa.gov/pr/health/faq.htm, January 30, 2007.

———, 2008. National Marine Fisheries Office of Protected Resources Memorandum to Chief of Naval Operations, Environmental Readiness. In review Jan 08.

National Oceanic and Atmospheric Administration (NOAA), 2001. Final Rule for the Shock Trial of the WINSTON S. CHURCHILL (DDG-81), Federal Register, Department of Commerce; NOAA Fisheries, FR 66, No. 87, 22450-67, 4 May.

————, 2002a. *Final Rule SURTASS LFA Sonar*. Federal Register, Department of Commerce, NOAA Fisheries. 16 July 2002. Federal Register (FR) 67, No 136, pp 46712–89

———, 2002b. *Report of the workshop on acoustic resonance as a source of tissue trauma in cetaceans.* NOAA Fisheries, Silver Spring, Maryland. April 2002.

———, 2006. Small takes of marine mammals incidental to specified activities, Rim of the Pacific antisubmarine warfare exercise training events within the Hawaiian Islands Operation Area. Federal Register 71:38710-38738, 7 Jul 06.

————, 2006a. Proposed Rule Taking and Importing Marine Mammals; Taking Marine Mammals Incidental to Conducting Precision Strike Weapons Testing and Training by Eglin Air Force Base in the Gulf of Mexico, Department of Commerce, NOAA Fisheries, *Federal Register*, Vol 71, No 149, pp 44001–12. 3 August 2006.

National Research Council (NRC), 1997. Proceedings of a dose-modeling workshop. December 13–14, 1997.

———, 2003. Ocean Noise and Marine Mammals. The National Academies Press, Washington, DC.

———, 2005. Marine Mammal Populations and Ocean Noise: Determining When Noise Causes Biologically Significant Effects. The National Academic Press, Washington D.C. 126 pp.

———, 2006. "Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options, Committee on Ecosystem Effects of Fishing: Phase II - Assessments of the Extent of Change and the Implications for Policy," (National Research Council, of the National Academes, National Academes Press, Washington, DC).

Nedler, J. A., and T. W. M. Wedderburn, 1972. Generalized linear models, *Journal of the RoyalStatistical Society*, Series A, 135: 370–384.

Nedwell, J. R., B. Edwards, A.W. H. Turnpenny, and J. Gordon. 2004. Fish and Marine Mammal Audiograms: A Summary of Available Information. 3 September 2004.

References

Norman, S. A., S. Raverty, W. McClellan, A. Pabst, D. Ketten, M. Fleetwood, J.K. Gaydos, Norberg, B., Barre, L., t. Cox, B. Hanson, and S. Jeffries, 2004. Multidisciplinary investigation of stranded harbor porpoises (*Phocoena phocoena*) in Washington State with an assessment of acoustic trauma as a contributory factor (2 May – 2 June 2003). U.S. Department of Commerce, NOAA Tech Memo NMFS-NWR-34. 120 pp.

Nowacek, D. P., M. P. Johnson, and P. L. Tyack, 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships but respond to alerting stimuli. Proceedings of the Royal Society B: Biological Sciences 271:227-231.

Occupational Safety and Health Administration (OSHA), 1996. "Occupational Exposure to 1,3-Butadiene," in OSHA safety and health standards 29 CFR Parts 1910 *Federal Register*. 61:56746-56856. November 4, 1996.

——————, 2006. "Occupational Exposure to Hexavalent Chromium," in OSHA safety and health standards 29 CFR Parts 1910 *Federal Register* 71:10099-10385. February 28, 2006.

Odell, D.K., 1987. The mystery of marine mammal strandings. Cetus 7:2.

Office of Naval Research (ONR), 1999a. LWAD 99-3 OEA "Overseas Environmental Assessment (OEA) for the Littoral Warfare Advanced Development (LWAD) 99-3 Sea Test," ONR Code 32, 22 July.

———— (ONR), 1999b. LWAD 99-2 OEA. "Overseas Environmental Assessment (OEA) for the Littoral Warfare Advanced Development (LWAD) 99-2 Sea Test." ONR Code 32, 15 April.

————(ONR), 2001. *Final Environmental Impact Statement for the North Pacific Acoustic* Laboratory, Volume I, May.

Perrin, W. F., and J. R. Geraci, 2002. "Stranding," in Encyclopedia of Marine Mammals, edited by W. F. Perrin, B. Wursig, and J. G. M. Thewissen (Academic Press, San Diego), pp. 1192-1197.

Piantadosi, C. A. and E. D. Thalmann, 2004. Whales, sonar, and decompression sickness. Nature. 15 April 2004.

Podesta, M., A. D'Amico, G. Pavan, A. Drouga, A. Komnenou, and N. Portunato, 2006). A review of *Ziphius cavirostris* strandings in the Mediterranean Sea. Journal of Cetacean Research and Mangagement 7(3):251-261.

Quaranta, A., P. Portalatini, and D. Henderson, 1998. "Temporary and permanent threshold shift: An overview," *Scandinavian Audiology*, 27:75–86.

Read, A. J., P. Drinker, and S. Northridge, 2006. "Bycatch of marine mammals in U.S. and global fisheries," Conservation Biology 20, 163-169.

Reeder, D. M. and K. M. Kramer, 2005. "Stress in free-range mammals: Integrating physiology, ecology, and natural history," *Journal of Mammalogy*. 86(2): 225-235.

Reeves, R.R., J.M. Breiwick, and E.D. Mitchell. 1999a. History of whaling and estimated kill of right whales, *Balaena glacialis*, in the northeastern United States, 1620-1924. Marine Fisheries Review 61(3):1-36.

Richardson, W. J., B. Wursig, and C. R. Greene, Jr., 1986. Reactions of bowhead whales, Balaena mysticetus, to seismic exploration in the Canadian Beaufort Sea. Journal of the Acoustical Society of America 79: 1117-1128.

Richardson, W. J., C. R. Greene Jr., W. R. Koski, C. I. Malme, G. W. Miller, M. A. Smultea, and B. Wursgi, 1990a. Acoustic effects of oil production activities on bowhead and white whales visible during spring migration near Pt. Barrow, Alaska – 1989 phase. Report prepared by LGL Environmental Research Associates Ltd. for the U.S. Department of the Interior, Minerals Management Service, Anchorage, Alaska. NTIS PB91-105486/.

Richardson, W. J., B. Wursig, and C. R. Greene, Jr., 1990b. Reactions of bowhead whales, Balaena mysticetes, to drilling and dredging noise in the Canadian Beaufort Sea. Marine Environmental Research 29: 135-160.

References

Richardson, W. J., C. R. Green, Jr., C. I. Malme, and D. H. Thomson, 1995. *Marine Mammals and Noise*, Academic Press, Inc., San Diego, CA.

Ridgway, S. H., and R. Howard, 1979. Dolphin lung collapse and intramuscular circulation during free diving: evidence from nitrogen washout. *Science*, Vol 206, pp 1182–1183.

Ridgway, S. H., D. A. Carder, R. R. Smith, T. Kamolnick, C. E. Schlundt, and W. R. Elsberry, 1997. Behavioral responses and temporary shift in masked hearing threshold of bottlenose dolphins, Tursiops truncatus, to 1-second tones of 141 to 201 dB re 1 µPa. Technical Report 1751, Revision 1. San Diego: Naval Sea Systems Command.

Runge, M. C., C. A. Sanders-Reed, C. A. Langtimm, and C. J. Fonnesbeck, 2007. *A Quantitative Threats Analysis for the Florida Manatee.*

Saunders, J. C., J. H. Mills, and J. D. Miller, 1977. "Threshold shift in the chinchilla from daily exposure to noise for six hours," Journal of the Acoustical Society of America, 61:558–570.

Schlundt, C. E., J. J. Finneran, D. A. Carder, and S. H. Ridgway, 2000. Temporary threshold shift in masked hearing thresholds of bottlenose dolphins, *Tursiops truncatus*, and white whales, *Delphinapterus leucas*, after exposure to intense tones. *Journal of the Acoustical Society of America*, Vol 107, pp 3496–3508.

Scowcroft, G., K. Vigness Raposa, C. Knowlton, and J. Johnen, 2006. *Discovery of Sound in the Sea*. University of Rhode Island.

Simmonds, M. P., and L. F. Lopez-Jurado, 1991. "Whales and the military," Nature 351, 448.

Southall, B., 2005. Shipping Noise and Marine Mammals: A Forum for Science, Management and Technology. National Oceanographic and Atmospheric Administration. 40 pp.

Stern, S. J., 2002. Migration and movement patterns. Pages 742-748 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Stevick, P. T., B. J. McConnell, and P. S. Hammond. 2002. Patterns of movement. Pages 185-216 in Hoelzel, A.R., ed. Marine mammal biology: An evolutionary approach. Oxford, United Kingdom: Blackwell Science.

Suter II, G. W., L. W. Barnthouse, S. M. Bartell, T. Mill, D. Mackay, and S. Paterson, 1993. *Ecological risk assessment*. Lewis Publishers, Boca Raton, Florida.

Tyack, P. L., M. Johnson, N. Aguilar Soto, A. Sturlese, and P. T. Madsen, 2006. Extreme diving of beaked whales. *Journal of Experimental Biology*, Vol 209, pp 4238–4253.

Urian, Kim W., Aleta A. Hohn and Larry J. Hansen, 1999. Status of the photo-identification catalog of coastal bottlenose dolphins of the western North Atlantic: report of a workshop of catalog contributors. U.S. Department of Commerce, Beaufort, NC. (NOAA Adminstrative Report NMFS-SEFSC-425) 24p. SH11.A3441a no.425.

Urick, R. J., 1983. *Principles of Underwater Sound, 3rd ed.* McGraw-Hill: New York.

USEPA, 1998. *EPA's Contaminated Sediment Management Strategy*. EPA-823-R-98-001. April 1998.

Vidal, O., and J. P. Gallo-Reynoso, 1996. "Die-offs of marine mammals and sea birds in the Gulf of California, Mexico," Mar. Mammal Sci. 12, 627-635.

Ward, W. D., 1960. Recovery from high values of temporary threshold shift. *Journal of the Acoustical Society of America*, Vol 32, pp 497–500.

Ward, W. D., 1997. Effects of high-intensity sound. *Encyclopedia of Acoustics*, ed. M.J. Crocker, Wiley: New York, New York, pp 1497–1507.

Ward, W. D., A. Glorig, and D. L. Sklar, 1958. Dependence of temporary threshold shift at 4 kc on intensity and time. *Journal of the Acoustical Society of America*, Vol 30, pp 944–954.

————, 1959. Temporary threshold shift from octave-band noise: Applications to damage-risk criteria. *Journal of the Acoustical Society of America*, Vol 31, pp 522–528.

Walsh, M. T., R. Y. Ewing, D. K. Odell, and G. D. Bossart2001. “Mass Strandings of Cetaceans,” in Marine Mammal Medicine, edited by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton), pp. 83-96.

Waring, G., D. Belden, M. Vecchione, and R. Gibbons, 2003. Mid-water prey in beaked whale and sperm whale deep-water habitat south of Georges Bank. In *Abstracts, Fifteenth Biennial Conference on the Biology of Marine Mammals 14–19 December 2003*, p 172. Greensboro, North Carolina.

Waring, G. T., E. Josephson, C. P. Fairfield, and K. Maze-Foley, editors., 2006. U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments -- 2005. NOAA Technical Memorandum NMFS-NE-194:1-346.

————, 2007. *U.S. Atlantic and Gulf of Mexico Marine Mammal Stock Assessments—2006*. NOAA Technical Memorandum, NMFS-NE-201. April 2007.

Wartzok, D., A. N. Popper, J. Gordon, and J. Merrill, 2003. Factors affecting the responses of marine mammals to acoustic disturbance. *Marine Technology Society Journal* 37(4):6-15.

Wells, R. S., D. J. Boness, and G. B. Rathbun, 1999. Behavior. Biology of Marine Mammals (ed. J.E. Reynolds III and S.A. Rommel), pp. 117-175.

Wilkinson, D. M., 1991. “Report to the Assistant Administrator for Fisheries, in Program Review of the Marine Mammal Stranding Networks,” (U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Silver Springs, MD), pp. 1-171.

Wingfield, J. C., 2003. Control of behavioural strategies for capricious environments. Animal Behavior, Vol 66, No 5, pp 807–816(10).

Yost, W. A., 1994. Fundamentals of Hearing: An Introduction. Academic Press: San Diego, California.

Zar, J. H., 1996. Biostatistical analysis. 3rd ed. Prentice Hall, Upper Saddle River, NJ.

APPENDIX A

SUPPLEMENTAL INFORMATION FOR UNDERWATER NOISE ANALYSIS

SUPPLEMENTAL INFORMATION FOR UNDERWATER NOISE ANALYSIS

A.1 ACOUSTIC SOURCES

The Naval Surface Warfare Center Panama City Division (NSWC PCD) research, development, test, and evaluation (RDT&E) acoustic sources are categorized as either broadband (producing sound over a wide frequency band) or narrowband (producing sound over a frequency band that that is small in comparison to the center frequency). Generally, the narrowband sources in these activities are active sonars and the broadband sources are explosives. This delineation of source types has a couple of implications. First, the transmission loss used to determine the impact ranges of narrowband active sonars can be adequately characterized by model estimates at a single frequency. Broadband explosives, on the other hand, produce significant acoustic energy across several frequency decades of bandwidth. Random-phase propagation loss is sufficiently sensitive to frequency as to require model estimates at a few frequencies over such a wide band; important coherent effects may require a significantly finer sampling in frequency.

Second, the types of sources have different sets of harassment metrics and thresholds. Energy metrics are defined for both types. However, explosives are impulsive sources that produce a shock wave that dictates additional pressure-related metrics (peak pressure and positive impulse). Detailed descriptions of both types of sources are provided in the following subsections.

A.1.1 Sonars

Operations in the NSWC PCD Study Area involve numerous types of band-limited, mid- and high-frequency sources. The permanent threshold shift (PTS) and temporary threshold shift (TTS) impact ranges for virtually all of these sources is less than the size of the source itself; the implication of the limited impact ranges is that the source is more likely to collide with a protected marine animal than harass it acoustically. This analysis focuses only on the loudest of these sources and demonstrates that even these sources yield few potential exposures (the Kingfisher being the lone significant exception). Exposure estimates are calculated for each source on a per-year basis. Table A-1 presents the frequency class and the reporting metric for each source, which represents the ranges of operating parameters of sonars typically used in RDT&E activities at NSWC PCD. Tables A-2 and A-3 gives an overview of the number of operating hours for each of these representative systems in territorial and non-territorial waters, respectively.

Table A-1. Representative Active Sonars Employed for NSWC PCD RDT&E Activities

Sonar	Description	Frequency Class	Exposures Reported
AN/SQS-53/56 Kingfisher	Surface ship object detection and navigation sonar (a mode of the AN/SQS-53/56).	Mid-frequency	Per year
Sub-bottom profiler (2-9 kHz)	A towed body projecting sonar into the seafloor for substrate survey. The center frequency for this system is 4.5 kHz.	Mid-frequency	Per year
REMUS SAS-LF	Object detection and navigation sonar on a UUV. The center frequency for this system is 15 kHz.	Mid-frequency	Per year
REMUS Modem	Acoustic communications modem on the REMUS UUV	Mid-frequency	Per year
Sub-bottom profiler (2-16 kHz)	A towed body projecting sonar into the seafloor for substrate survey. The center frequency for this system is 9 kHz.	Mid-frequency	Per year
AN/SQQ-32	Towed mine detection sonar on surface ships	High frequency	Per year
REMUS-SAS-LF	Object detection and navigation sonar on a UUV. The center frequency for this system is 25 kHz.	High frequency	Per year
SAS-LF	Object detection and navigation sonar. The center frequency for this system is 20 kHz.	High frequency	Per year
AN/WLD-1 RMS-ACL	The acoustic communications sonar of the ship-launched Remote Minehunting System UUV.	High frequency	Per year
BPAUV Sidescan	Battlespace Preparation Autonomous Underwater Vehicle sonar, an AUV used for mine detection. The center frequency for this system is 75 kHz.	High frequency	Per year
TVSS	Toroidal Volume Search Sonar, an experimental bottom moored system using toroidal beamforming	High frequency	Per year
F84Y	Tower-mounted parametric sonar used to simulate mine-like objects	High frequency	Per year
BPAUV Sidescan	Battlespace Preparation Autonomous Underwater Vehicle sonar, an AUV used for mine detection. The center frequency for this system is 102.5 kHz.	High frequency	Per year
REMUS-SAS-HF	Object detection and navigation sonar on a UUV.	High frequency	Per year
SAS-HF	Object detection and navigation sonar.	High frequency	Per year
AN/AQS-20	Helicopter-towed deep-water mine detection sonar	High frequency	Per year
AN/WLD-11 RMS Navigation	Navigation sonar used on the ship-launched Remote Minehunting System UUV.	High frequency	Per year
BPAUV Sidescan	Battlespace Preparation Autonomous Underwater Vehicle sonar, an AUV used for mine detection. The center frequency for this system is 120 kHz.	High frequency	Per year

kHz = kilohertz; UUV = underwater unmanned vehicle; AUV = autonomous underwater vehicle

Table A-2. Hours of Sonar Operations by Representative System for Territorial Waters

System	Alternative 2
AN/SQS-53/56 Kingfisher	3
Sub-bottom profiler (2-9 kHz)	21
REMUS SAS-LF	12
REMUS Modem	25
Sub-bottom profiler (2-16 kHz)	24
AN/SQQ-32	30
REMUS-SAS-LF	20
SAS-LF	35
AN/WLD-1 RMS-ACL	33.5
BPAUV Sidescan	25
TVSS	15
F84Y	15
BPAUV Sidescan	25
REMUS-SAS-HF	10
SAS-HF	11.5
AN/AQS-20	545
AN/WLD-11 RMS Navigation	15
BPAUV Sidescan	30

Table A-3. Hours of Sonar Operations by Representative System for Non-Territorial Waters

System	Alternative 2
AN/SQS-53/56 Kingfisher	1
Sub-bottom profiler (2-9 kHz)	1
REMUS SAS-LF	0
REMUS Modem	12
Sub-bottom profiler (2-16 kHz)	1
AN/SQQ-32	1
REMUS-SAS-LF	0
SAS-LF	15
AN/WLD-1 RMS-ACL	5
BPAUV Sidescan	38
TVSS	16.5
F84Y	15
BPAUV Sidescan	0
REMUS-SAS-HF	25
SAS-HF	15
AN/AQS-20	15
AN/WLD-11 RMS Navigation	0
BPAUV Sidescan	25

The acoustic modeling that is necessary to support the exposure estimates for each of these sonars relies upon a generalized description of the manner of the sonar's operating modes. This description includes the following:

- "Effective" energy source level – The total energy across the band of the source, scaled by the pulse length (10 log10 [pulse length]), and corrected for source beam width so that it reflects the energy in the direction of the main lobe. The beam pattern correction consists of two terms:
  - Horizontal directivity correction: $10 \log_{10}$(360 / horizontal beam width)

   - Vertical directivity correction: $10 \log_{10} (2 / [\sin(\theta_1) - \sin(\theta_2)])$, where θ_1 and θ_2 are the 3-decibel (dB) down points on the main lobe.

- Source depth – Depth of the source in meters.
- Nominal frequency – Typically the center band of the source emission. These are frequencies that have been reported in open literature and are used to avoid classification issues. Differences between these nominal values and actual source frequencies are small enough to be of little consequence to the output impact volumes.
- Source directivity – The source beam is modeled as the product of a horizontal beam pattern and a vertical beam pattern. Two parameters define the horizontal beam pattern:
   - Horizontal beam width – Width of the source beam (degrees) in the horizontal plane (assumed constant for all horizontal steer directions).
   - Horizontal steer direction – Direction in the horizontal in which the beam is steered relative to the direction in which the platform is heading.

The horizontal beam is rectangular with constant response across the width of the beam and with flat, 20 dB down sidelobes. (Note that steer directions ϕ, $-\phi$, $180^o - \phi$, and $180^o + \phi$ all produce equal impact volumes.)

- Similarly, two parameters define the vertical beam pattern:
   - Vertical beam width (D/E) – Width of the source beam (degrees) in the vertical plane measured at the 3 dB down point. (The width is that of the beam steered towards broadside and not the width of the beam at the specified vertical steer direction.)
   - Vertical steer direction – Direction in the vertical plane that the beam is steered relative to the horizontal (upward looking angles are positive).

  To avoid sharp transitions that a rectangular beam might introduce, the power response at vertical angle θ is

$$\max \{ \sin^2 [n(\theta_s - \theta)] / [n \sin (\theta_s - \theta)]^2, \; 0.01 \}$$

  where $n = 180^o / \theta_w$ is the number of half-wavelength-spaced elements in a line array that produces a main lobe with a beam width of θ_w. θ_s is the vertical beam steer direction.

- Ping spacing – Distance between pings. For most sources this is generally just the product of the speed of advance of the platform and the repetition rate of the sonar. Animal motion is generally of no consequence as long as the source motion is greater than the speed of the animal (nominally, three knots). For stationary (or nearly stationary) sources, the "average" speed of the animal is used in place of the platform speed. The attendant assumption is that the animals are all moving in the same constant direction.

These parameters are defined for each of the active sonars in the following table:

Table A-4. Source Description of NSWC PCD RDT&E Active Sonars

System	Center Frequency (kHz)	Sound Pressure Level (dB)	Pulse Length (sec)	Emission Spacing (m)	D/E Angle (°)	D/E Width (°)	Azimuth Angle (°)	Azimuth Width (°)
AN/SQS-53/56 Kingfisher	3.5	235	0.1	9.0	42	20	0	120
Sub-bottom profiler (2-9 kHz)	4.5	205	0.007	3.0	Omni	Omni	90	90
REMUS SAS-LF	15	205	0.01	1.9	60	30	80	50
REMUS Modem	10	186	5	45.0	0	60	0	Omni
Sub-bottom profiler (2-16 kHz)	9	200	0.02	0.2	45	20	90	20
AN/SQQ-32	26	118	0.00044	3.0	0	30	9.8	70
REMUS-SAS-LF	25	215	0.01	1.9	60	Omni	80	240
SAS-LF	20	212	0.0001	0.6	60	30	80	50
AN/WLD-1 RMS-ACL	20	215	0.004	360.0	45	90	90	30
BPAUV Sidescan	75	210	0.013	0.2	10	70	90	0.8
TVSS	68	220	0.0001	4.0	90	3	0	Omni
F84Y	65	232	0.004	1.5	0	Omni	0	Omni
BPAUV Sidescan	102.5	226	0.002	0.4	0	55	90	0.5
REMUS SAS-HF	180	220	0.01	1.9	25	9	9	15
SAS-HF	180	214	0.000033	0.6	25	9	9	15
AN/AQS-20	35	212	0.00432	6.0	45	90	90	30
AN/WLD-11 RMS Navigation	300	223	0.001	3.0	30	2.3	30	2.3
BPAUV Sidescan	120	210	0.0083	0.1	10	70	90	0.8

kHz = kilohertz; dB = decibels; sec = seconds; m = meters; ° = degrees

For the sources that are essentially stationary (AN/SSQ-62 and AN/AQS-22), emission spacing is the product of the ping cycle time and the average animal speed.

A.1.2. Explosives

Explosives detonated underwater introduce loud, impulsive, broadband sounds into the marine environment. Three source parameters influence the effect of an explosive: the weight of the explosive warhead, the type of explosive material, and the detonation depth. The net explosive weight (or net explosive weight [NEW]) accounts for the first two parameters. The NEW of an explosive is the weight of only the explosive material in a given round, referenced to the explosive power of trinitrotoluene (TNT).

The detonation depth of an explosive is particularly important due to a propagation effect known as surface-image interference increasingly. For sources located near the sea surface, a distinct interference pattern arises from the coherent sum of the two paths that differ only by a single reflection from the pressure-release surface. As the source depth and/or the source frequency decreases, these two paths increasingly, destructively interfere with each other, reaching total cancellation at the surface (barring surface-reflection scattering loss). For the NSWC PCD Study Area there are three types of explosive sources: demolition charges, mines, and mine-clearing line charges. Table A-5 provides an overview of the ordnance used in NSWC PCD RDT&E activities along with their NEW and detonation depth. Consistent with earlier VAST/IMPASS modeling, a source depth of 0.3 meters (m) (1 foot [ft]) is used for gunnery round.

Table A-5. Explosive Sources for NSWC PCD RDT&E Activities

Ordnance	NEW kilograms (pounds)	Depth in meters (feet)	Location
MK-58 Line Charge	793.8 (1,750)	Bottom	Surf zone
Explosive	4.5 (10)	15.2 (50)	100-1,000 ft of water
Mine	34 (75)	15.2 (50)	On-shelf outside 22.2 km (12 NM) territorial limit
Mine	199.6 (440)	Bottom	On-shelf outside 22.2 km (12 NM) territorial limit
Mine	272.2 (600)	36.6 (120)	On-shelf outside 22.2 km (12 NM) territorial limit

ft = feet; km = kilometers; NM = nautical miles

The harassments expected to result from these ordnances are computed on a per in-water explosive basis. The cumulative effect of a series of explosives can often be derived by simple addition if the detonations are spaced widely in time or space, allowing for sufficient animal movement as to ensure that a different population of animals is considered for each detonation.

A.2 IMPACT VOLUMES AND IMPACT RANGES

Naval actions include the potential to injure or harass marine animals in the neighboring waters through noise emissions. The number of animals exposed to potential harassment in any such action is dictated by the propagation field and the characteristics of the noise source.

The impact volume associated with a particular activity is defined as the volume of water in which some acoustic metric exceeds a specified threshold. The product of this impact volume with a volumetric animal density yields the expected value of the number of animals exposed to that acoustic metric at a level that exceeds the threshold. The acoustic metric can either be an energy term (energy flux density, either in a limited frequency band or across the full band) or a pressure term (such as peak pressure or positive impulse). The thresholds associated with each of these metrics define the levels at which half of the animals exposed will experience some degree of harassment (ranging from behavioral change to mortality).

Impact volume is particularly relevant when trying to estimate the effect of repeated source emissions separated in either time or space. Impact range, which is defined as the maximum range at which a particular threshold is exceeded for a single source emission, is used to define the range to which marine mammal activity is monitored in order to meet mitigation requirements.

With the exception of explosive sources, the sole relevant measure of potential harm to the marine wildlife due to sonar operations is the accumulated (summed over all source emissions) energy flux density received by the animal over the duration of the activity. Harassment measures for explosive sources include energy flux density and pressure-related metrics (peak pressure and positive impulse).

Regardless of the type of source, estimating the number of animals that that may be exposed to the potential risk of harassment in a particular environment entails the following steps.

- Each source emission is modeled according to the particular operating mode of the sonar. The "effective" energy source level is computed by integrating over the bandwidth of the source, scaling by the pulse length, and adjusting for gains due to source directivity. The location of the source at the time of each emission must also be specified.
- For the relevant environmental acoustic parameters, transmission loss (TL) estimates are computed, sampling the water column over the appropriate depth and range intervals. TL data are sampled at the typical depth(s) of the source and at the nominal center frequency of the source. If the source is relatively broadband, an average over several frequency samples is required.
- The accumulated energy within the waters that the source is "operating" is sampled over a volumetric grid. At each grid point, the received energy from each source emission is modeled as the effective energy source level reduced by the appropriate propagation loss from the location of the source at the time of the emission to that grid point and summed. For the peak pressure or positive impulse, the appropriate metric is similarly modeled for each emission. The maximum value of that metric (over all emissions) is stored at each grid point.
- The impact volume for a given threshold is estimated by summing the incremental volumes represented by each grid point for which the appropriate metric exceeds that threshold.
- Finally, the number of exposures is estimated as the "product" (scalar or vector, depending upon whether an animal density depth profile is available) of the impact volume and the animal densities.

This section describes in detail the process of computing impact volumes (that is, the first four steps described above). This discussion is presented in two parts: active sonars and explosive sources. The relevant assumptions associated with this approach and the limitations that are implied are also presented. The final step, computing the number of exposures is discussed in Subsection A.5.

A.2.1 Computing Impact Volumes for Active Sonars

This section provides a detailed description of the approach taken to compute impact volumes for active sonars. Included in this discussion are:

- Identification of the underwater propagation model used to compute transmission loss data, a listing of the source-related inputs to that model, and a description of the output parameters that are passed to the energy accumulation algorithm.
- Definitions of the parameters describing each sonar type.
- Description of the algorithms and sampling rates associated with the energy accumulation algorithm.

The following bullets provide an overview of the steps in simplistic terms followed by detailed information for the calculations.

- Step 1. Environmental Provinces. The NSWC PCD Study Area is divided into 16 environmental provinces, and each has a unique combination of environmental conditions. These represent various combinations of eight bathymetry provinces, one Sound Velocity Profile (SVP) province, and three Low-Frequency Bottom Loss geo-acoustic provinces and two High-Frequency Bottom Loss classes. These are addressed by defining environments in two seasons that span the variety of depths, bottom types, sound speed profiles, and sediment thicknesses found in the NSWC PCD Study Area. The two seasons encompass winter and summer, which are the two extremes and for the GOM the acoustic propagation characteristics do not vary significantly between the two. Each marine modeling area can be quantitatively described as a unique combination of these environments.

- Step 2. Transmission Loss. Since sound propagates differently in these environments, separate transmission loss calculations must be made for each, in both seasons. The transmission loss is predicted using CASS-GRAB sound modeling software.

- Step 3. Exposure Volumes. The transmission loss, combined with the source characteristics, gives the energy field of a single ping. The energy of over 10 hours of pinging is summed, carefully accounting for overlap of several pings, so an accurate average exposure of an hour of pinging is calculated for each depth increment. At more than ten hours, the source is too far away and the energy is negligible. In addition, the acoustic modeling takes into account the use of a single system. Only one source will operate at any one time during NSWC PCD RDT&E activities.

  Repeating this calculation for each environment in each season gives the hourly ensonified volume, by depth, for each environment and season. This step begins the method for risk function modeling.

- Step 4. Marine Mammal Densities. The marine mammal densities were given in two dimensions, but using peer-reviewed literature sources (published literature and agency reports) described in the following subsection, the depth regimes of these marine mammals are used to project the two dimensional densities (expressed as the number of animals per area where all individuals are assumed to be at the water's surface) into three dimensions (a volumetric approach whereby two-dimensional animal density incorporates depth into the estimates).

- Step 5. Exposure Calculations. Each marine mammal's three-dimensional density is multiplied by the calculated impact volume—to that marine mammal depth regime. This value is the number of exposures per hour for that particular marine mammal. In this way, each marine mammal's exposure count per hour is based on its density, depth habitat, and the ensonified volume by depth.

Transmission Loss Calculations

TL data are pre-computed for each of two seasons in the five environmental provinces described in the previous subsection using the Gaussian Ray Bundle (GRAB) propagation loss model (Keenan, 2000). The use of GRAB is predicated on the following factors:

- GRAB is certified as a Navy-standard transmission loss model over the frequency regime of interest.
- GRAB describes the propagation field parametrically by a set of eigenrays (propagation paths connecting source to receiver), which affords the following modeling efficiencies:
  - The source vertical directivity does not need to be included at the time of the TL calculation, allowing alternative source directivities to be modeled without additional TL calculations.
  - TL estimates at a given frequency can be extrapolated to other "nearby" frequencies by simply correcting for differences in absorption loss thus potentially reducing the number of TL calculations.
  - The coherent effects of surface-image interference that persist over range can be accounted for with a simple model that does not require an unwieldy number of TL model runs across frequency.

The TL output consists of data describing each significant eigenray (or propagation path) including the departure angle from the source (used to model the source vertical directivity later in this process), the propagation time from the source to the animal (used to make corrections to absorption loss for minor differences in frequency and to incorporate a surface-image interference correction at low frequencies), and the transmission loss suffered along the eigenray path.

The frequency TL inputs are specified in Table A-6.

Table A-6. TL Frequency and Source Depth by Sonar Type

Sonar	TL Input Frequency
Kingfisher	3.5 kHz
Sub-bottom Profiler (2-9 kHz)	3.5 kHz
SAS-LF	15 kHz
REMUS Modem	7.5 kHz
Sub-bottom Profiler (2-16 kHz)	7.5 kHz
AN/SQQ-32	35 kHz
REMUS-SAS-LF	35 kHz
SAS-LF	15 kHz
RMS-ACL	15 kHz
BPAU Sidescan (75 kHz)	75 kHz

Sonar	TL Input Frequency
TVSS	75 kHz
F84Y	75 kHz
BPAU Sidescan (95-110 kHz)	75 kHz
REMUS-SAS-HF	150 kHz
SAS-HF	150 kHz
AN/AQS-20	35 kHz
RMS Navigation	350 kHz
BPAU Sidescan	150 kHz

TL = transmission loss; kHz = kilohertz

In most cases, the actual frequency of the source is somewhat different from the input frequency of the TL calculation. To account for this difference, the TL for each eigenray is adjusted for the difference in absorption loss between the two frequencies. The path length of the eigenray is estimated as the product of the eigenray's travel time and a nominal sound speed of 1,500 meters per second (m/sec). Generally, this correction is relatively small at the ranges of interest and only becomes significantly large at ranges that are well beyond the impact range.

The eigenray data for a single GRAB model run are sampled at uniform increments in range out to a maximum range for a specific "animal" (or "target" in GRAB terminology) depth. Multiple GRAB runs are made to sample the animal depth dependence. The depth and range sampling parameters are summarized in Table A-7. Note that these parameters are a function of the TL input frequency; Table A-7 can be used to map them to a particular sonar source.

Table A-7. TL Depth and Range Sampling Parameters by Sonar Type

Frequency	Range Step	Maximum Range	Animal Depth Step
3.5 kHz	10 m (32.8 ft)	150 km (80.9 NM)	5 m (16.4 ft)
7.5 kHz	10 m (32.8 ft)	100 km (53.96 NM)	5 m (16.4 ft)
15 kHz	10 m (32.8 ft)	50 km 926.98 NM)	5 m (16.4 ft)
35 kHz	10 m (32.8 ft)	20 km (10.8 NM)	5 m (16.4 ft)
75 kHz	10 m (32.8 ft)	10 km (5.4 NM)	5 m (16.4 ft)
150 kHz	10 m (32.8 ft)	5 km (2.7 NM)	5 m (16.4 ft)
350 kHz	10 m (32.8 ft)	5 km (2.7 NM)	5 m (16.4 ft)
750 kHz	10 m (32.8 ft)	5 km (2.7 NM)	5 m (16.4 ft)

kHz = kilohertz; ft = feet; km = kilometers; NM = nautical miles; m = meters

Although GRAB provides the option of including the effect of source directivity in its eigenray output, this capability is not exercised. By preserving data at the eigenray level, this allows source directivity to be applied later in the process and results in fewer TL calculations.

The other important feature that storing eigenray data supports is the ability to model the effects of surface-image interference that persist over range. However, this is primarily important at frequencies lower than those associated with the sonars considered in this subsection. A detailed description of the modeling of surface-image interference is presented in the subsection on explosive sources.

Energy Summation

The summation of energy flux density over multiple pings in a range-independent environment is a straight forward exercise for the most part. A volumetric grid that covers the waters in and around the area of sonar operation is initialized. The source then begins its set of pings. For the first ping, the TL from the source to each grid point is determined (summing the appropriate eigenrays after they have been modified by the vertical beam pattern), the "effective" energy source level is reduced by that TL, and the result is added to the accumulated energy flux density at that grid point. After each grid point has been updated, the accumulate energy at grid points in each depth layer is compared to the specified threshold. If the accumulate energy exceeds that threshold, then the incremental volume represented by that grid point is added to the impact volume for that depth layer. Once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for one ping.

The source is then moved along one of the axes in the horizontal plane by the specified ping separation range and the second ping is processed in a similar fashion. Again, once all grid points have been processed, the resulting sum of the incremental volumes represents the impact volume for two pings. This procedure continues until the maximum number of pings specified has been reached.

Defining the volumetric grid over which energy is accumulated is the trickiest aspect of this procedure. The volume must be large enough to contain all volumetric cells for which the accumulated energy is likely to exceed the threshold but not so large as to make the energy accumulation computationally unmanageable.

Determining the size of the volumetric grid begins with an iterative process to determine the lateral extent to be considered. Unless otherwise noted, throughout this process the source is treated as directional and the only animal depth that is considered is the TL target depth that is closest to the source depth (placing source and receiver at the same depth is generally an optimal TL geometry).

The first step is to determine the impact range for a single ping. The impact range in this case is the maximum range (R_{max}) at which the effective energy source level reduced by the transmission loss is greater than the threshold. Next the source is moved along a straight-line track and energy flux density is accumulated at a point that has a Closest Points of Approach (CPA) range of R_{max} at the mid-point of the source track. That total energy flux density summed over all pings is then compared to the prescribed threshold. If it is greater than the threshold (which, for the first R_{max}, it must be) then R_{max} is increased by ten percent, the accumulation process is repeated, and the total energy is again compared to the threshold. This continues until R_{max} grows large enough to ensure that the accumulated energy flux density at that lateral range is less than the threshold. The lateral range dimension of the volumetric grid is then set at twice R_{max}, with the grid centered along the source track. In the direction of advance for the source, the volumetric grid extends of the interval from [$-R_{max}$, 3 R_{max}] with the first source position located at zero in this dimension. Note that the source motion in this direction is limited to the interval [0, 2 R_{max}]. Once the source reaches 2 R_{max} in this direction, the incremental volume contributions have approximately reached their asymptotic limit and further pings add essentially the same amount. This geometry is demonstrated in Figure A-1.

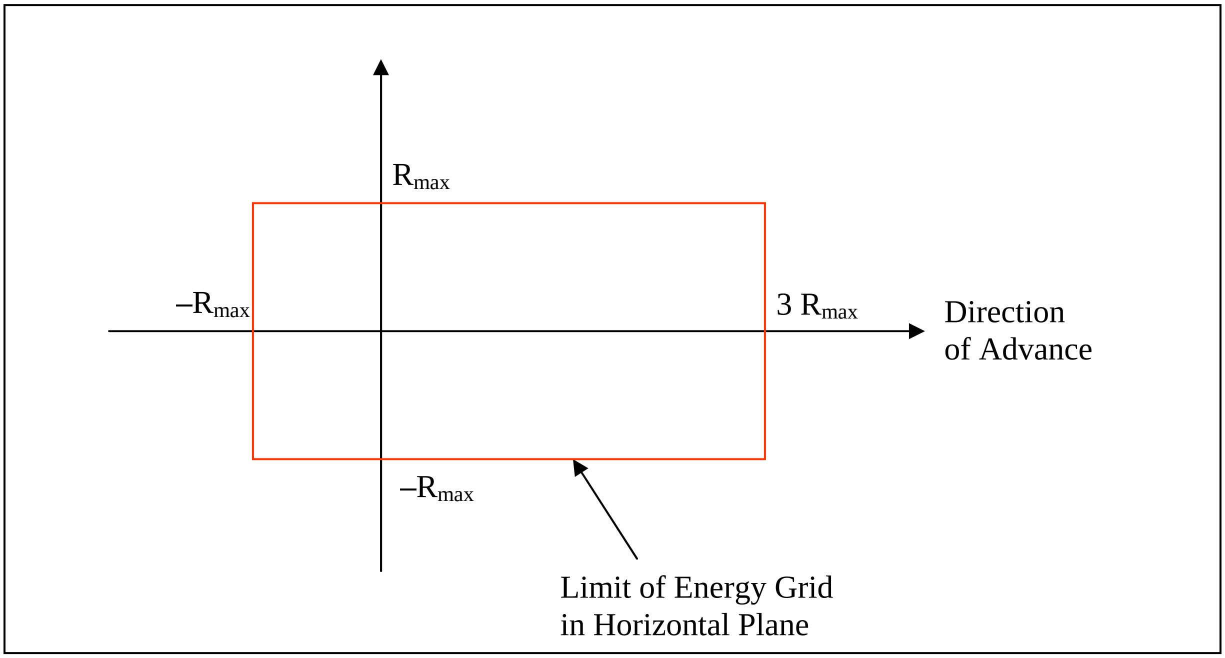


Figure A-1. Horizontal Plane of Volumetric Grid for Omni-Directional Source

If the source is directive in the horizontal plane, then the lateral dimension of the grid may be reduced and the position of the source track adjusted accordingly. For example, if the main lobe of the horizontal source beam is limited to the starboard side of the source platform, then the port side of the track is reduced substantially as demonstrated in Figure A-2.

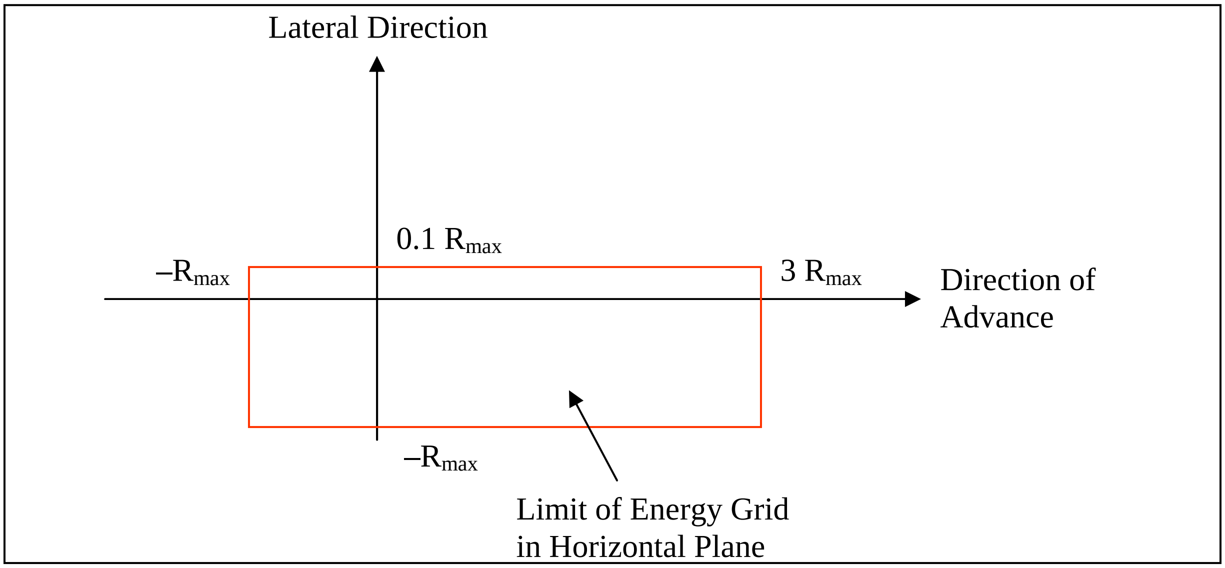


Figure A-2. Horizontal Plane of Volumetric Grid for Starboard Beam Source

Once the extent of the grid is established, the grid sampling can be defined. In the both dimensions of the horizontal plane the sampling rate is approximately $R_{max}/100$. The round-off error associated with this sampling rate is roughly equivalent to the error in a numerical integration to determine the area of a circle with a radius of R_{max} with a partitioning rate of $R_{max}/100$ (approximately one percent). The depth-sampling rate of the grid is comparable to the sampling rates in the horizontal plane but discretized to match an actual TL sampling depth. The depth-sampling rate is also limited to no more that 10 m to ensure that significant TL variability over depth is captured.

Impact Volume per Hour of Sonar Operation

The impact volume for a sonar moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases varies with a number of parameters but eventually approaches some asymptotic limit. Beyond that point the increase in impact volume becomes essentially linear, as depicted in the following figure.

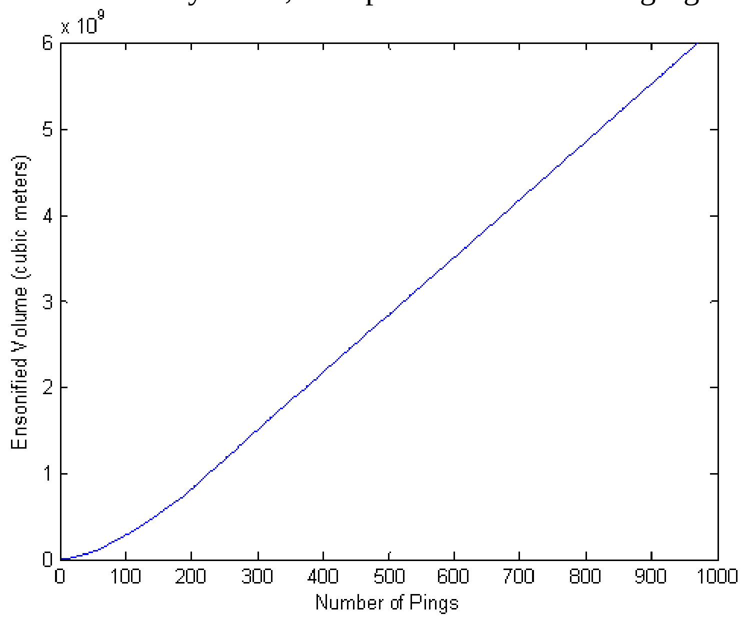


Figure A-3. 53C Impact Volume by Ping

The slope of the asymptotic limit of the impact volume at a given depth is the impact volume added per ping. This number multiplied by the number of pings in an hour gives the hourly impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the hourly impact volume vector, v_n, which contains the hourly impact volumes by depth for province n. Figure A-4 provides an example of an hourly impact volume vector for a particular environment.

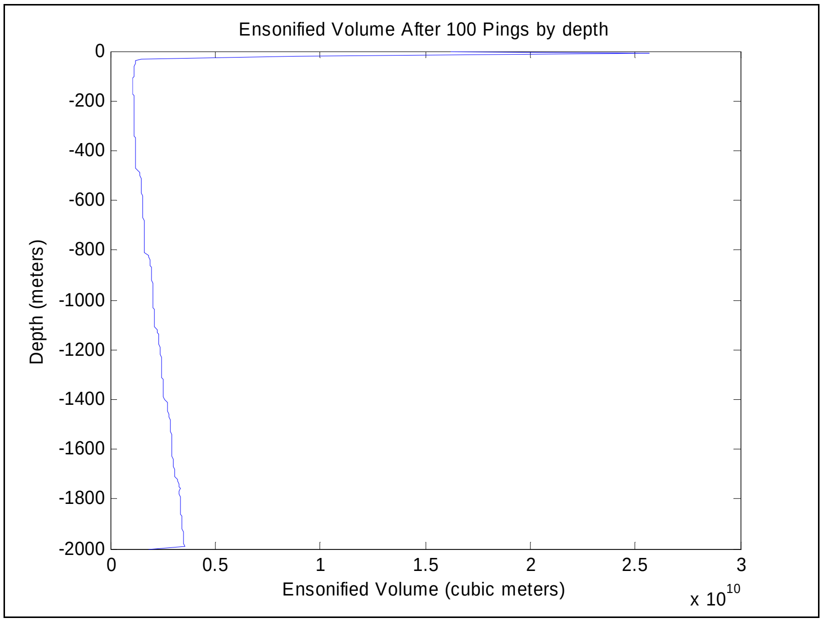


Figure A-4. Example of an Impact Volume Vector

A.2.2 Computing Impact Volumes for Explosive Sources

This section provides the details of the modeling of the explosive sources. This energy summation algorithm is similar to that used for sonars, only differing in details such as the sampling rates and source parameters. These differences are summarized in the following subsections. A more significant difference is that the explosive sources require the modeling of additional pressure metrics: (1) peak pressure, and (2) "modified" positive impulse. The modeling of each of these metrics is described in detail in a following subsection on special considerations for the MK-58 line charge.

Transmission Loss Calculations

Modeling impact volumes for explosive sources span requires the same type of TL data as needed for active sonars. However unlike active sonars, explosive ordnances are very broadband, contributing significant energy from tens of Hertz (Hz) to tens of kilohertz (kHz). To accommodate the broadband nature of these sources, TL data are sampled at seven frequencies from 10 Hz to 40 kHz, spaced every two octaves. This rather coarse sampling in frequency is justified as long as path-level transmission loss varies smoothly with frequency and random-phase addition of eigenrays is used.

An important consideration for coherent propagation loss, particularly at low frequencies, is the effect of surface-image interference. As either source or target approach the surface, pairs of paths that differ in history by a single surface reflection set up an interference pattern that ultimately causes the two paths to perfectly 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 at all depths 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 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:

$$\sin^2 [\, 4\pi\, f\, z_s\, z_a / (c^2\, t)\,]$$

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.

A final important consideration is the broadband nature of explosive sources. This is handled by sampling the TL field at a limited number of frequencies. However, the image-interference correction given above varies substantially over that frequency spacing. To avoid possible under sampling, the image-interference correction is finely sampled and averaged over each frequency interval.

Source Parameters

Unlike active sonars, explosive sources are defined by only two parameters: (1) net explosive weight, and (2) source detonation depth. Values for these source parameters are defined earlier in the section on explosive acoustic sources.

The effective energy source level, which is treated as a de facto input for the sonar sources, is instead modeled directly for explosives. The energy source level is comparable to the model used for other explosives [Arons (1954), Weston (1960), McGrath (1971), Urick (1983), Christian and Gaspin (1974)]. For a source with an NEW of w points, the energy source level over a one-third-octave band with a center frequency of *f* is

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

where the peak pressure for the shock wave at 1 m is defined as

$$p_{max} = 21600\, (w^{1/3} / 3.28\,)^{1.13} \;\; \text{psi} \qquad \text{(A-1)}$$

and the time constant is defined as:

$$\theta = [(0.058)\, (w^{1/3})\, (3.28 / w^{1/3})^{\,0.22}\,] / 1000 \text{ msec} \qquad \text{(A-2)}$$

Special Considerations for MK-58 Line Charge

The MK-58 line charge differs from the other explosive sources in three significant aspects:

- The MK-58 is exclusively used in very shallow water.
- The source is not a single explosive but rather a large number of explosives.
- These explosives are arranged in a line and fired more or less simultaneously.

Limiting the deployment of the MK-58 to very shallow water, specifically the surf zone, serves to emphasize the importance of surface-image interference. Placement in the surf zone, modeled here as being 2 m (6.6 ft) deep, emphasizes the decoupling due to surface-image interference that arises from source or receiver (or in this case both) being located near the surface. With source and receiver both within 2 m (6.6 ft) of the sea surface, propagation loss is affected up to relatively high frequencies (5 kHz or more), including the peak in the spectrum of this source. Given the prominence of surface-image interference in this problem, it is critical to consider what factors might limit this effect.

The expression used to model surface-image interference is based on the assumption that surface reflection loss is negligible for the propagation paths of interest. If this is not the case, then the pairs of paths that would be modeled as canceling each other might, in fact, be different enough in amplitude to make the cancellation far less than complete, leading to more favorable propagation and greatly extending the impact range of the source. By way of example, modifying the expression use to model surface-image interference to include surface loss of as little as 0.1 dB increases the impact area (and hence the number of animal exposures) by as much as nearly a factor of three. Similarly, including a surface loss of 1 dB can increase the impact area by more than a factor of 1,000, while a totally random phase addition of these paths would increase the impact area by a factor several orders of magnitude greater.

This sensitivity to surface loss is of particular importance given that the sea surface is hardly placid in the surf zone. Breaking waves produce a reflecting surface that is rougher than what would normally be predicted for the specified wind speed; a rougher surface necessarily implies greater scattering loss. In addition, the layer of near-surface bubbles that are created by the breaking waves serves to further scatter and attenuate propagating sound.

On the other hand, the concern about surface loss is at least partially mitigated by the fact that the dominant propagation paths quickly become quite shallow as range increases (less than 2 degrees at 1 kilometer (0.54 nautical mile [NM]) and shallow-angle paths generally tend to suffer very little surface loss. Furthermore, the entire area of interest

Given the complexity of the competing forces, this analysis used the same model of surface-image interference for the MK-58 source as for the other explosive sources. It is recognized that this may result in an underestimate of the number of animal exposures, but short of a carefully conducted measurement (clearly beyond the scope of this effort) to validate this or some other model any other approach is equally arbitrary.

At low frequencies, modeling in such shallow water must focus on propagation through the sediment layer(s) rather than treating the bottom as a boundary with a particular reflection loss. As frequency increases though, absorption loss within the sediment increases thus reducing the importance of bottom-penetrating paths. The sandy bottom that is characteristic of the area of interest has an attenuation rate of more than 28 dB / kilometer [0.54 NM] at 1 kHz, with the rate varying directly with frequency and increasing linearly with depth within the sediment.

The second significant aspect is that the MK-58 line charge consists of 350 explosives, each with an explosive weight of 2.27 kilograms (kg) (5 pounds [lbs]), arranged in a line and spaced at 0.3 m (1 ft). This yields a total net explosive weight for the line charge of 794 kg (1,750 lbs).

For the pressure metrics (peak pressure and modified positive impulse), the source is modeled according to its physical characteristics. The impact range, R, for a single 2.27 kg (5 lbs) explosive is derived and the impact area for that single explosive is computed as πR^2. If the explosives are sufficiently far apart (that is, the spacing is greater than 2R), then the collective impact area for the 350 explosives would simply by 350 πR^2. However, if the impact areas of neighboring explosives do overlap, then the amount of overlap of each consecutive pair, given by the expression

$$2\ R^2\ \mathrm{acos}(0.5/R) - \ \mathrm{sqrt}\ (R^2 - 0.25),$$

must be removed, yielding a collective impact area of

$$350\ \pi R^2 - 349\ [2\ R^2\ \mathrm{acos}(0.5/R) - \ \mathrm{sqrt}\ (R^2 - 0.25)].$$

For the energy metrics, a similar view of the collective source mass is appropriate to an extent. The energy source spectrum is defined for a single 2.27 kg (5 lbs) explosive (see previous subsection), which is then scaled by the number of explosives (350 or 10 $\log_{10}(350)$ in dB-space). This results in an energy source spectrum with a peak one-third-octave level in the neighborhood of 1,500 Hz, rather than a peak near 300 Hz as is characteristic of a 794 kg (1,750 lbs) source.

Next, the configuration and firing of the MK-58 explosives is such that the line charge acts like a horizontal line array with a main lobe near broadside to either side of the array. (The burn rate of the det cord that is used to ignite the sources introduces a delay in their firing that results in a main lobe that is steered roughly ten degrees off broadside. However, this steering makes no appreciable difference in this analysis.) The beam pattern of this array is modeled as a "square beam" (that is, the main lobe has a constant beam power over the width of the beam) with a constant sidelobe level that is 30 dB below that of the main lobe. The width of the main lobe (in radians) is defined as λ / L, where λ is the acoustic wave length and L is the length of the array (107 m, or 350 ft). The beam power response on the main lobe is adjusted as a function of frequency to ensure that the total power in the beam pattern is equal to that of an omnidirectional source with a beam power response of unity.

The impact range for the 182 dB threshold is greatest for the one-third-octave that is centered near 1.8 kHz. At this frequency, propagation is effectively limited to very shallow paths that have little interaction with a bottom that has an absorption loss of greater than 50 dB per kilometer. While this absorption rate diminishes with frequency, the improvement in propagation is counterbalanced by increases in the surface decoupling.

Impact Volumes for Various Metrics

The impact of explosive sources on marine wildlife is measured by three different metrics, each with its own thresholds. The energy metric, peak one-third-octave, is treated in similar fashion as the energy metric used for the active sonars, including the summation of energy if there are multiple source emissions. The other two, peak pressure and positive impulse, are not accumulated but rather the maximum levels are taken.

Peak One-Third-Octave Energy Metric

The computation of impact volumes for the energy metric follows closely the approach taken to model the energy metric for the active sonars. The only significant difference is that energy flux density is sampled at several frequencies in one-third-octave bands and only the peak one-third-octave level is accumulated.

Peak Pressure Metric

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 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 (given by equation M-1), 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.

"Modified" Positive Impulse Metric

The modeling of positive impulse follows the work of Goertner (Goertner, 1982). 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 $t < 0$. This pressure wave is modeled as

$$p(t) = p_{max}\, e^{-t/\theta}$$

where p_{max} is the peak pressure at one meter (see, equation B-1), and θ is the time constant defined as

$$\theta = 0.058\, w^{1/3} (r/w^{1/3})^{0.22} \text{ seconds}$$

with w the net explosive weight (pounds), and r the slant range between source and animal.

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 [ft]).

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 20; for the onset of extensive lung hemorrhaging (1 percent mortality), K is 43.

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 calf dolphin (with an average mass of 12.2 kg [27 lbs]). For the onset of slight lung injury, the threshold at the surface is approximately 13 pounds per square inch per millisecond (psi-msec); for the onset of extensive lung hemorrhaging (1 percent 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.

Impact Volume per Explosive Detonation

The detonations of explosive sources are generally widely spaced in time and/or space. This implies that the impact volume for multiple firings can easily be derived by scaling the impact volume for a single detonation. Thus the typical impact volume vector for an explosive source is presented on a per detonation basis.

Impact Volume by Region

The NSWC PCD Study Area is described by eleven environmental provinces. The hourly impact volume vector for operations involving any particular source is a linear combination of the eleven impact volume vectors with the weighting determined by the distribution of those eleven environmental provinces within the source's operation area. Unique hourly impact volume vectors for winter and summer are calculated for each type of source and each metric/threshold combination.

A.3 RISK FUNCTION: THEORETICAL AND PRACTICAL IMPLEMENTATION

This section discusses the recent addition of a risk response "threshold" for the acoustic effects analysis procedure. This approach includes two parts: a new metric and a function to map exposure level under the new metric to probability of harassment. The following subsections discuss what these two parts mean, how they affect exposure calculations, and how they are implemented.

A.3.1 Calculation of Expected Exposures

Determining the number of expected exposures for disturbance is the object of this analysis.

$$\text{Expected exposures in volume } V = \int_V \rho(V) D(m_a(V)) dV$$

Where ρ is the animal density at a given point, or set of points.

For this analysis, $m_a = m_{\max SPL}$, so

$$\int_V \rho(V) D(m_a(V)dV = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \rho(x,y,z) D(m_{\max SPL}(x,y,z)) dxdydz$$

In this analysis, the densities are constant over the *x*-*y* plane, and the *z* dimension is always negative, so this reduces to

$$\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z)) dxdydz$$

A.3.2 Numeric Integration

Numeric integration of $\int_{-\infty}^{\infty} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z)) dxdydz$ can be involved because, although the bounds are infinite, D is nonnegative out to 141 dB, which, depending on the environmental specifics, can drive propagation loss calculations and their numerical integration out to more than 100 km.

The first step in the solution is to separate out the *x*-*y* plane portion of the integral:

$$\text{Define } f(z)= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdy .$$

Calculation of this integral is the most involved and time-consuming part of the calculation. Once it is complete,

$$\int_{-\infty}^{0}\rho(z)\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz = \int_{-\infty}^{0}\rho(z)f(z)dz ,$$

which, when numerically integrated, is a simple dot product of two vectors.

Thus, the calculation of *f(z)* requires the majority of the computation resources for the numerical integration. The rest of this subsection outlines the steps to calculate *f(z)* and preserve the results efficiently.

The concept of numerical integration is, instead of integrating over continuous functions, to sample the functions at small intervals and sum the samples to approximate the integral. The smaller the size of the intervals, the closer the approximation but the longer the calculation; thus, a balance between accuracy and time is determined in the decision of step size. For this analysis, *z* is sampled in 5 m (16.4 ft) steps to 1,000 m (3,281 ft) deep and 10 m (33 ft) steps to 2,000 m (6,562 ft), which is the limit of animal depth in this analysis. The step size for *x* is 5 m (16.4 ft), and *y* is sampled with an interval that increases as the distance from the source increases. Mathematically,

$$\begin{aligned} z &\in Z = \{0,5,...1000,1010,...,2000\} \\ x &\in X = \{0,\pm 5,...,\pm 5k\} \\ y &\in Y = \{0,\pm 5(1.005)^0, 5 \pm (1.005)^1, \pm 5(1.005)^2,...,5(1.005)^j\} \end{aligned}$$

for integers *k*, *j*, which depend on the propagation distance for the source. For this analysis, *k* = 20,000 and *j* = 600.

Following these steps, $f(z_0) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z_0))dxdy$ is approximated as

$$\sum_{z\in Y}\sum_{x\in X} D(m_{\max SPL}(x,y,z_0))\Delta x \Delta y$$

where *X*, *Y* are defined as above.

This calculation must be repeated for each $z_0 \in Z$, to build the discrete function *f(z).*

With the calculation of *f(z)* complete, the integral of its product with $\rho(z)$ must be calculated to complete evaluation of

$$\int_{-\infty}^{\infty} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz = \int_{-\infty}^{0} \rho(z) f(z)dz$$

Since *f(z)* is discrete, and $\rho(z)$ can be readily made discrete, This is approximated numerically as $\sum_{z \in Z} \rho(z) f(z)$, a dot product.

Preserving Calculations for Future Use

Calculating *f(z)* is the most time-consuming part of the numerical integration, but the most time-consuming portion of the entire process is calculating $m_{\max SPL}(x,y,z)$ over the area range required for the minimum cutoff value (141 dB). The calculations usually require propagation estimates out to over 100 km, and those estimates, with the beam pattern, are used to construct a sound field that extends 200 km × 200 km (124 miles x 124 miles), or 40,000 km^2 (15,444 square miles), with a calculation at the steps for every value of *X* and *Y*, defined above. This is repeated for each depth, to a maximum of 2,000 m (6,562 ft).

Saving the entire $m_{\max SPL}$ for each *z* is unrealistic, requiring great amounts of time and disk space. Instead, the different levels in the range of $m_{\max SPL}$ are sorted into bins of 0.5 dB; the volume of water at each bin level is taken from $m_{\max SPL}$ and associated with its bin. Saving this, the amount of water ensonified at each level, at 0.5-dB resolution, preserves the ensonification information without using the space and time required to save $m_{\max SPL}$ itself. Practically, this is a histogram of occurrence of level at each depth, with 0.5-dB bins. Mathematically, this is simply defining the discrete functions $V_z(L)$, where $L = \{.5a\}$ for every positive integer a, for all $z \in Z$. These functions, or histograms, are saved for future work. The information lost by saving only the histograms is *where* in space the different levels occur, although *how often* they occur is saved. But the thresholds (risk function curves) are purely a function of level, not location, so this information is sufficient to calculate *f(z).*

Applying the risk function to the histograms is a dot product:

$$\sum_{\ell \in L_1} D(\ell) V_{z_0}(\ell) \approx \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z_0))dxdy$$

Once the histograms are saved, neither $m_{\max SPL}(x,y,z)$ nor *f(z)* must be recalculated to generate $\int_{-\infty}^{0} \rho(z) \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} D(m_{\max SPL}(x,y,z))dxdydz$ for a new threshold function.

The following subsection includes an in-depth discussion of the method, software, and other details of the *f(z)* calculation.

Software Details

The risk function metric uses the cumulative normal probability distribution to determine the probability that an animal is affected by a given sound pressure level. The probability distribution is defined by a mean, standard deviation, and low-level cutoff, below which it is assumed that animals are not affected. The acoustic quantity of interest is the maximum sound pressure level experienced over multiple pings in a range-independent environment. The procedure for calculating the impact volume at a given depth is relatively simple. In brief, given the sound pressure level of the source and the TL curve, the sound pressure level is calculated on a volumetric grid. For a given depth, volume associated with a sound pressure level interval is calculated. Then this volume is multiplied by the probability that an animal will be affected by that sound pressure level. This gives the impact volume for that depth, which can be multiplied by the animal densities at that depth to obtain the number of animals affected at that depth. The process repeats for each depth to construct the impact volume as a function of depth.

The case of a single emission of sonar energy, one ping, illustrates the computational process in more detail. First, the sound pressure levels are segregated into a sequence of bins that cover the range encountered in the area. The sound pressure levels are used to define a volumetric grid of the local sound field. The impact volume for each depth is calculated as follows: for each depth in the volumetric grid, the sound pressure level at each *x-y* plane grid point is calculated using the sound pressure level of the source, the TL curve, the horizontal beam pattern of the source, and the vertical beam patterns of the source. The sound pressure levels in this grid become the bins in the volume histogram. Figure A-5 shows a volume histogram for a low-power sonar. Level bins are 0.5 dB in width and the depth is 50 m (164 ft) in an environment with water depth of 100 m (328 ft). The oscillatory structure at very low levels is due the flattening of the TL curve at long distances from the source, which magnifies the fluctuations of the TL as a function of range. The "expected" impact volume for a given level at a given depth is calculated by multiplying the volume in each level bin by the risk probability function at that level. Total expected impact volume for a given depth is the sum of these "expected" volumes. Figure A-6 is an example of the impact volume as a function of depth at a water depth of 100 m (328 ft).

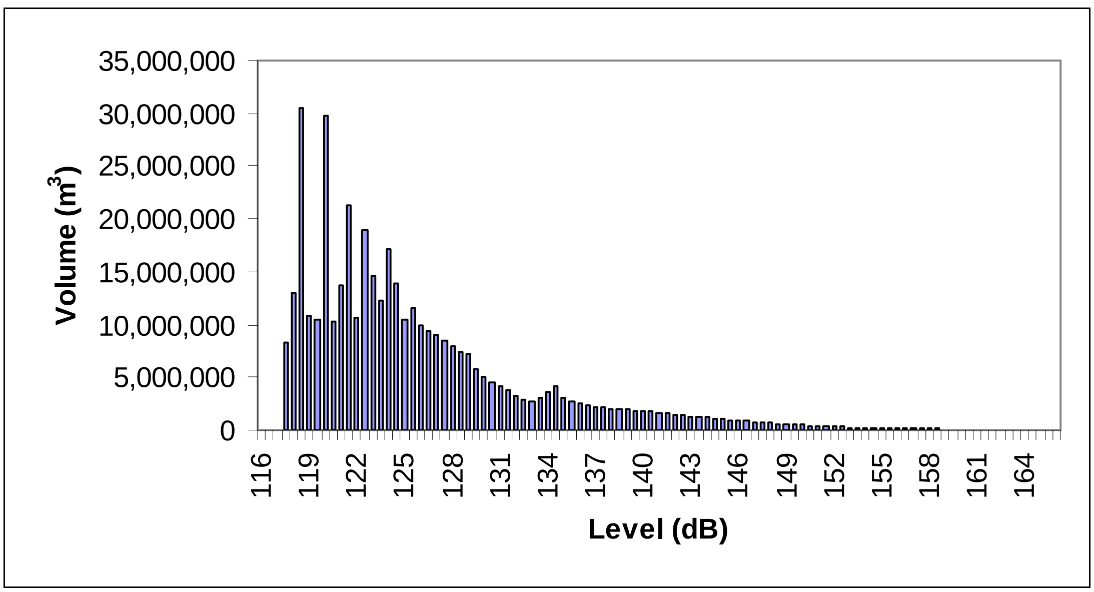


Figure A-5. Example of a Volume Histogram

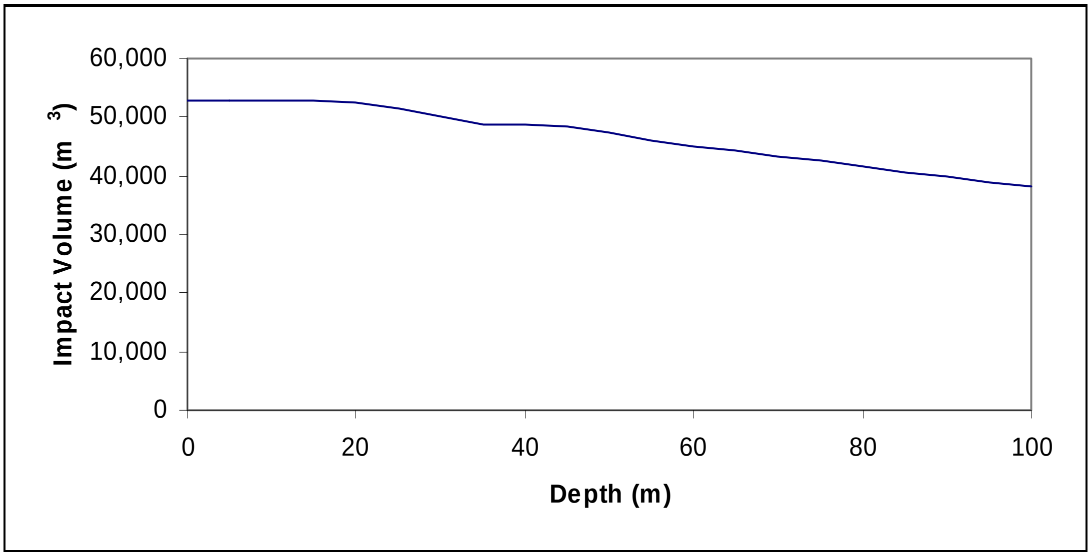


Figure A-6. Example of the Dependence of Impact Volume

The volumetric grid covers the waters in and around the area of sonar operation. The grid for this analysis has a uniform spacing of 5 m (16.4 ft) in the *x* coordinate and a slowly expanding spacing in the *y* coordinate that starts with 5 m (16.4 ft) spacing at the origin. The growth of the grid size along the *y* axis is a geometric series. Each successive grid size is obtained from the previous by multiplying it by 1 + *Ry*, where *Ry* is the *y* axis growth factor. This forms a geometric series. The n^{th} grid size is related to the first grid size by multiplying by $(1+Ry)^{(n-1)}$. For an initial grid size of 5 m (16.4 ft) and a growth factor of 0.005, the 100th grid increment is 8.19 m (26.9 ft). The constant spacing in the *x* coordinate allows greater accuracy as the source moves along the *x* axis. The slowly increasing spacing in *y* reduces computation time, while maintaining accuracy, by taking advantage of the fact that TL changes more slowly at longer distances from the source. The *x* and *y* coordinates extend from $-R_{max}$ to $+R_{max}$, where R_{max} is the maximum range used in the TL calculations. The *z* direction uses a uniform spacing of 5 m (16.4 ft) down to 1,000 m (3,281 ft) and 10 m (33 ft) from 1,000 to 2,000 m (3,281 to 6,562 ft). This is the same depth mesh used for the effective energy metric as described above. The depth mesh does not extend below 2,000 m (6,562 ft), on the assumption that animals of interest are not found below this depth.

Figures A-7, A-8, and A-9 indicate how the accuracy of the calculation of impact volume depends on the parameters used to generate the mesh in the horizontal plane. Figure A-7 shows the relative change of impact volume for one ping as a function of the grid size used for the *x* axis. The *y* axis grid size is fixed at 5 m (16.4 ft), and the *y* axis growth factor is 0, i.e., uniform spacing. The impact volume for a 5 m (16.4 ft) grid size is the reference. For grid sizes between 2.5 and 7.5 m (8.3 and 24.6 ft), the change is less than 0.1 percent. A grid size of 5 m (16.4 ft) for the *x* axis is used in the calculations. Figure A-8 shows the relative change of impact volume for one ping as a function of the grid size used for the *y* axis. The *x* axis grid size is fixed at 5 m (16.4 ft), and the *y* axis growth factor is 0. The impact volume for a 5 m (16.4 ft) grid size is the reference. This figure is very similar to that for the *x* axis grid size. For grid sizes between 2.5 and 7.5 m (8.2 and 24.6 ft), the change is less than 0.1 percent. A grid size of 5 m (16.4 ft) is used for the *y* axis in our calculations. Figure A-9 shows the relative change of impact volume for one ping as a function of the *y* axis growth factor. The *x* axis grid size is fixed at 5 m and the initial *y* axis grid size is 5 m (16.4 ft). The impact volume for a growth factor of 0 is the reference. For growth factors from 0 to 0.01, the change is less than 0.1 percent. A growth factor of 0.005 is used in the calculations.

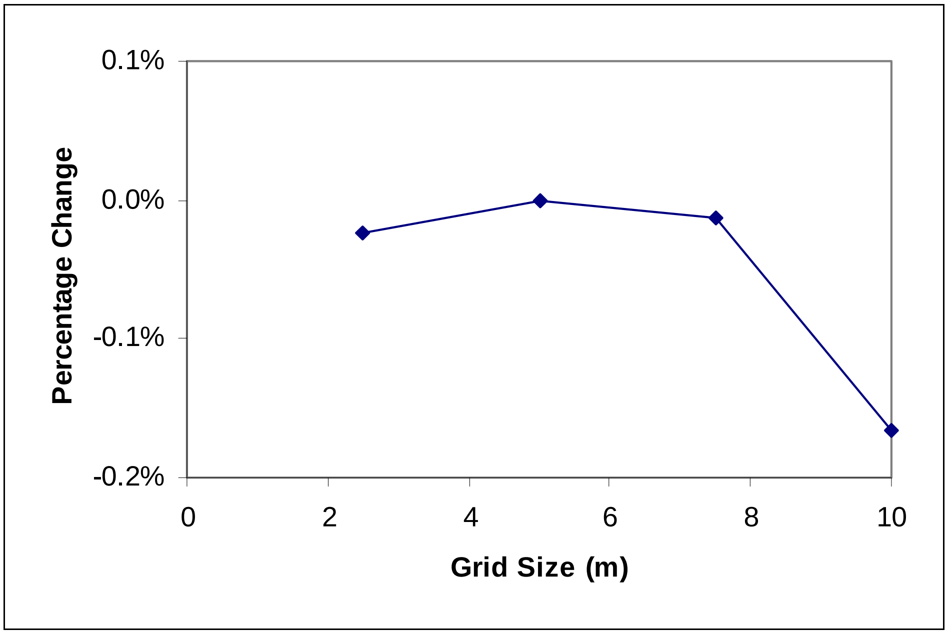


Figure A-7. Change of Impact Volume as a Function of *X* Axis Grid Size

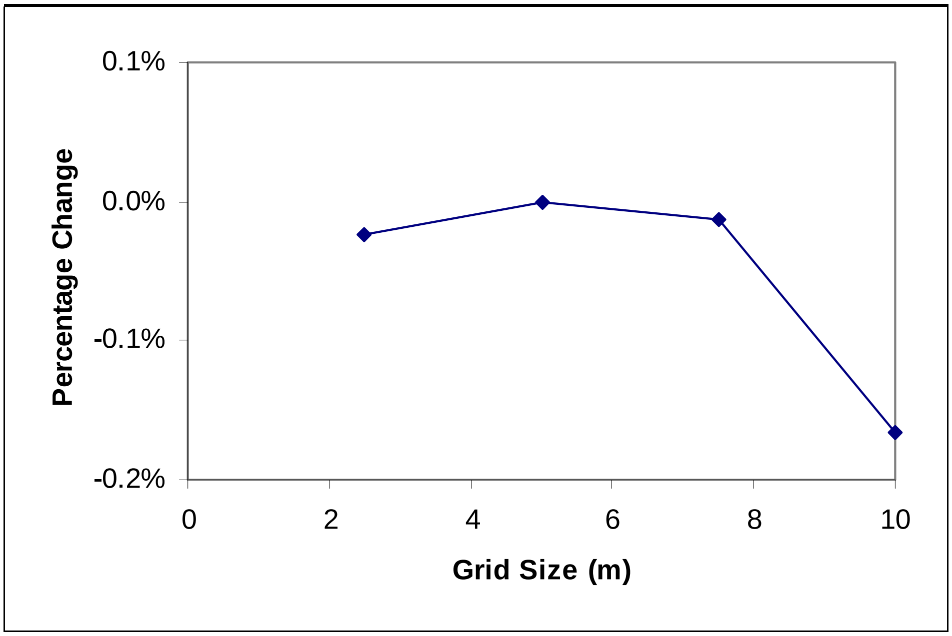


Figure A-8. Change of Impact Volume as a Function of *Y* Axis Grid Size

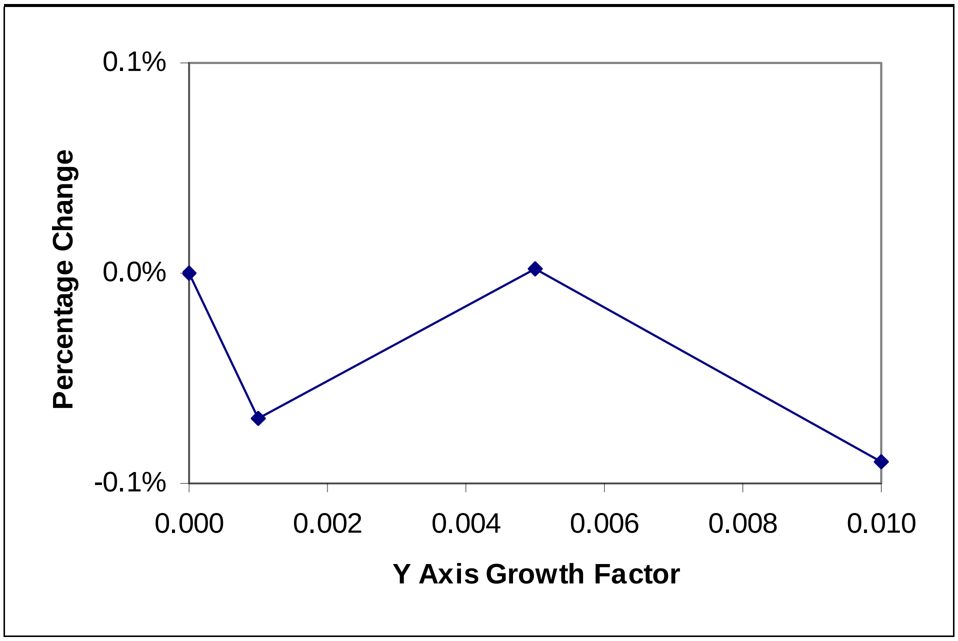


Figure A-9. Change of Impact Volume as a Function of *Y* Axis Growth Factor

Another factor influencing the accuracy of the calculation of impact volumes is the size of the bins used for sound pressure level. The sound pressure level bins extend from 100 dB (far lower than required) up to 300 dB (much higher than that expected for any sonar system). Figure A-10 shows the relative change of impact volume for one ping as a function of the bin width. The *x* axis grid size is fixed at 5 m (16.4 ft), the initial *y* axis grid size is 5 m (16.4 ft), and the *y* axis growth factor is 0.005. The impact volume for a bin size of 0.5 dB is the reference. For bin widths from 0.25 dB to 1.00 dB, the change is about 0.1 percent. A bin width of 0.5 is used in our calculations.

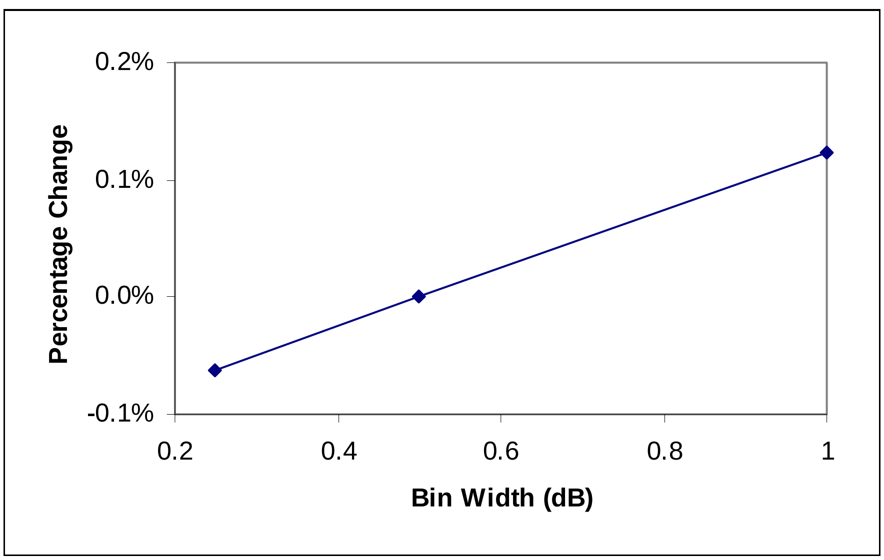


Figure A-10. Change of Impact Volume as a Function of Bin Width

Two other issues for discussion are the maximum range (R_{max}) and the spacing in range and depth used for calculating TL. The TL generated for the energy accumulation metric is used for risk function analysis. The same sampling in range and depth is adequate for this metric because it requires a less-demanding computation (i.e., maximum value instead of accumulated energy). Using the same value of R_{max} needs some discussion since it is not clear that the same value can be used for both metrics. R_{max} was set so that the TL at R_{max} is more than needed to reach the energy accumulation threshold of 173 dB for 1,000 pings. Since energy is accumulated, the same TL can be used for one ping with the source level increased by 30 dB (10 $\log_{10}$(1,000)). Reducing the source level by 30 dB, to get back to its original value, permits the handling of a sound pressure level threshold down to 143 dB, comparable to the minimum required. Hence, the TL calculated to support energy accumulation for 1,000 pings will also support calculation of impact volumes for the risk function metric.

The process of obtaining the maximum sound pressure level at each grid point in the volumetric grid is straightforward. The active sonar starts at the origin and moves at constant speed along the positive *x* axis, emitting a burst of energy, a ping, at regularly spaced intervals. For each ping, the distance and horizontal angle connecting the sonar to each grid point is computed. Calculating the TL from the source to a grid point involves several steps. The TL is made up of the sum of many eigenrays connecting the source to the grid point. The beam pattern of the source is applied to the eigenrays based on the angle at which they leave the source. After summing the vertically beam-formed eigenrays on the range mesh used for the TL calculation, the vertically beam-formed TL for the distance from the sonar to the grid point is derived by interpolation. Next, the horizontal beam pattern of the source is applied using the horizontal angle connecting the sonar to the grid point. To avoid problems in extrapolating TL, only use grid points with distances less than R_{max} are used. To obtain the sound pressure level at a grid point, the sound pressure level of the source is reduced by that TL. For the first ping, the volumetric grid is populated by the calculated sound pressure level at each grid point. For the second ping and subsequent pings, the source location increments along the *x* axis by the spacing between pings and the sound pressure level for each grid point is again calculated for the new source location. Since the risk function metric uses the maximum of the sound pressure levels at each grid point, the newly calculated sound pressure level at each grid point is compared to the sound pressure level stored in the grid. If the new level is larger than the stored level, the value at that grid point is replaced by the new sound pressure level.

For each bin, a volume is determined by summing the ensonified volumes with a maximum SPL in the bin's interval. This forms the volume histogram shown in Figure A-5. Multiplying by the risk probability function for the level at the center of a bin gives the impact volume for that bin. The result can be seen in Figure A-6, which is an example of the impact volume as a function of depth.

The impact volume for a sonar moving relative to the animal population increases with each additional ping. The rate at which the impact volume increases for the risk function metric is essentially linear with the number of pings. Figure A-11 shows the dependence of impact volume on the number of pings. The function is linear; the slope of the line at a given depth is the impact volume added per ping. This number multiplied by the number of pings in an hour gives the hourly impact volume for the given depth increment. Completing this calculation for all depths in a province, for a given source, gives the hourly impact volume vector, which contains the hourly impact volumes by depth for a province. Figure A-12 provides an example of an hourly impact volume vector for a particular environment. Given the speed of the sonar, the hourly impact volume vector could be displayed as the impact volume vector per kilometer of track.

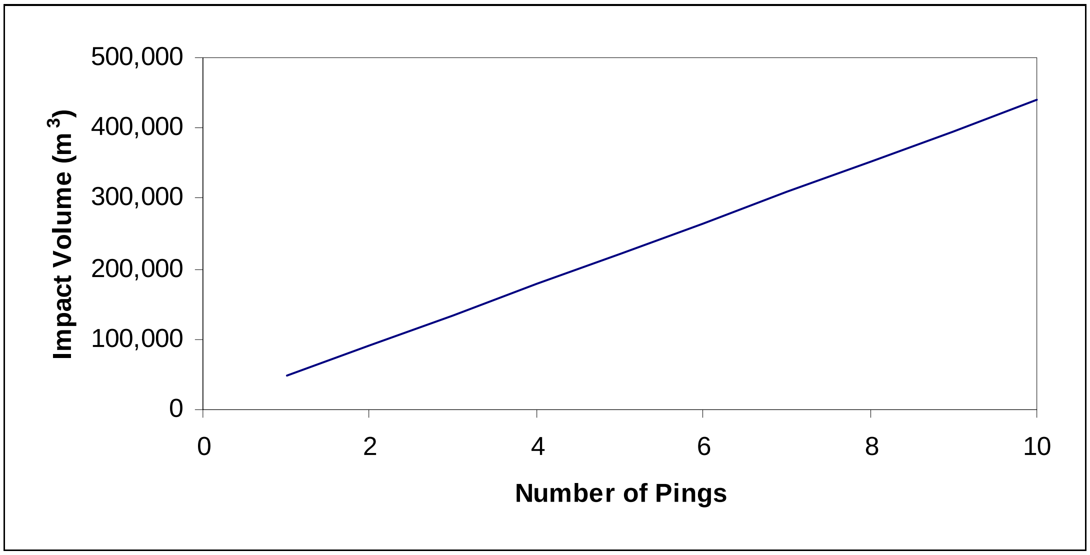


Figure A-11. Dependence of Impact Volume on the Number of Pings

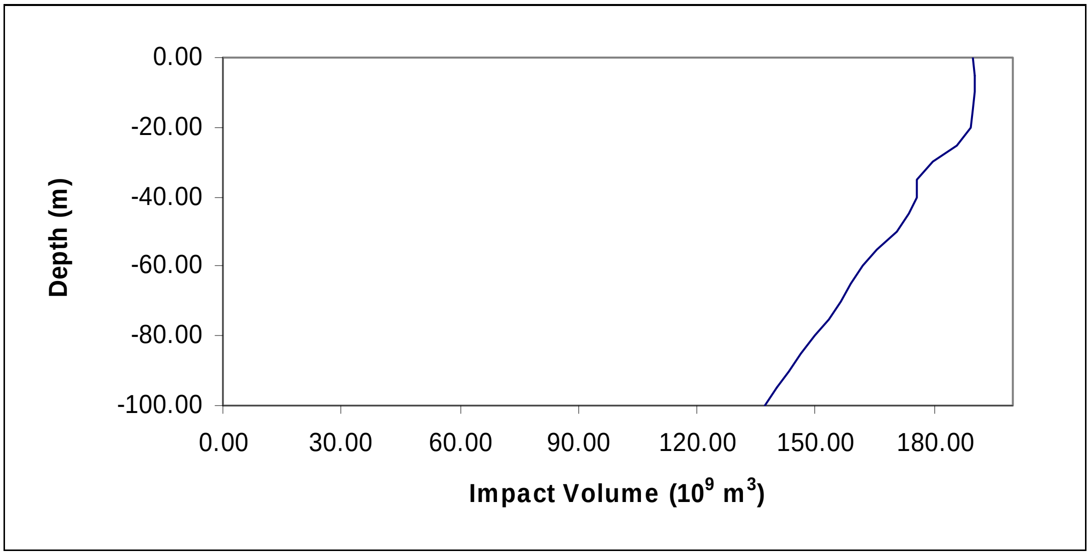


Figure A-12. Example of an Hourly Impact Volume Vector

A.4 ADDITIONAL MODELING CONSIDERATIONS IN A GENERAL MODELING SCENARIO

When modeling the effect of sound projectors in the water, the ideal task presents modelers with complete *a priori* knowledge of the location of the source(s) and transmission patterns during the times of interest. In these cases, calculation inputs include the details of source path, proximity of shoreline, high-resolution density estimates, and other details of the scenario. However, in the NSWC PCD Study Area, there are sound-producing events for which the source locations and transmission patterns are unknown, but still require analysis to predict effects. For these cases, a more general modeling approach is required: "We will be operating somewhere in this large area for X hours. What are the potential effects on average? "

Modeling these general scenarios requires a statistical approach to incorporate the scenario nuances into harassment calculations. For example, one may ask: "If an animal receives 130 dB SPL when the source passes at closest point of approach (CPA) on Tuesday morning, how do we know it doesn't receive a higher level on Tuesday afternoon?" This question cannot be answered without knowing the path of the source (and several other facts). Because the path of the source is unknown, the number of an individual's re-exposures cannot be calculated directly. But it can, on average, be accounted for by making appropriate assumptions.

Table A-8 lists unknowns created by uncertainty about the specifics of a future proposed action, the portion of the calculation to which they are relevant, and the assumption that allows the effect to be computed without the detailed information.

Table A-8. Unknowns and Assumptions

Unknowns	Relevance	Assumption
Path of source(esp. with respect to animals)	Ambiguity of multiple exposures, Local population: upper bound of harassments	Most conservative case: sources can be anywhere within Area
Source locations	Ambiguity of multiple exposures, land shadow	Equal distribution of action in each modeling area
Direction of sonar transmission	Land shadow	Equal probability of pointing any direction

The following sections discuss two topics that require action details, and describe how the modeling calculations used the general knowledge and assumptions to overcome the future-action uncertainty with respect to re-exposure of animals, and land shadow.

A.4.1 Multiple Exposures in General Modeling Scenario

Consider the following hypothetical scenario. A box is painted on the surface of a well-studied ocean environment with well-known propagation. A sonar-source and 1000 whales are inserted into that box and a curtain is drawn. What will happen? This is the general scenario. The details of what will happen behind the curtain are unknown, but the existing knowledge, and general assumptions, can allow for a general calculation of average affects.

For the first period of time, the source is traveling in a straight line and pinging at a given rate. In this time, it is known how many animals, on average, receive their max SPLs from each ping. As long as the source travels in a straight line, this calculation is valid. However, after an undetermined amount of time, the source will change course to a new and unknown heading.

If the source changes direction 180 degrees and travels back through the same swath of ocean, all the animals the source passes at closest point of approach (CPA) before the next course change have already been exposed to what will be their maximum SPL, so the population is not "fresh." If the direction does not change, only new animals will receive what will be their maximum SPL from that source (though most have received sound from it), so the population is completely "fresh." Most source headings lead to a population of a mixed "freshness," varying by course direction. Since the route and position of the source over time are unknown, the freshness of the population at CPA with the source is unknown. This ambiguity continues through the remainder of the exercise.

What is known? The source and, in general, the animals remain in the NSWC PCD Study Area. Thus, if the farthest range to a possible effect from the source is X km, no animals farther than X km outside of the OPAREA can be harassed. The intersection of this area with a given animal's habitat multiplied by the density of that animal in its habitat represents the maximum number of animals that can be harassed by activity in that SOA, which shall be defined as "the local population." Two details: first, this maximum should be adjusted down if a risk function is being used, because not 100% of animals within X km of the OPAREA border will be harassed. Second, it should be adjusted up to account for animal motion in and out of the area.

The ambiguity of population freshness throughout the exercise means that multiple exposures cannot be calculated for any individual animal. It must be dealt with generally at the population level.

Solution to the Ambiguity of Multiple Exposures in the General Modeling Scenario

At any given time, each member of the population has received a maximum SPL (possibly zero) that indicates the probability of harassment in the exercise. This probability indicates the contribution of that individual to the expected value of the number of harassments. For example, if an animal receives a level that indicates 50% probability of harassment, it contributes 0.5 to the sum of the expected number of harassments. If it is passed later with a higher level that indicates a 70 percent chance of harassment, its contribution increases to 0.7. If two animals receive a level that indicates 50 percent probability of harassment, they together contribute 1 to the sum of the expected number of harassments. That is, we statistically expect exactly one of them to be harassed. Let the expected value of harassments at a given time be defined as "the harassed population" and the difference between the local population (as defined above) and the harassed population be defined as "the unharassed population." As the exercise progresses, the harassed population will never decrease and the unharassed population will never increase.

The unharassed population represents the number of animals statistically "available" for harassment. Since we do not know where the source is, or where these animals are, we assume an average (uniform) distribution of the unharassed population over the area of interest. The densities of unharassed animals are lower than the total population density because some animals in the local population are in the harassed population.

Density relates linearly to expected harassments. If action A in an area with a density of two animals per square kilometer produces 100 expected harassments, then action A in an area with one animal per square kilometer produces 50 expected harassments. The modeling produces the number of expected harassments per ping starting with 100 percent of the population unharassed. The next ping will produce slightly fewer harassments because the pool of unharassed animals is slightly less.

For example, consider the case where 1 animal is harassed per ping when the local population is 100, 100 percent of which are initially unharassed. After the first ping, 99 animals are unharassed, so the number of animals harassed during the second ping are

$10\left(\frac{99}{100}\right) = 1(.99) = 0.99$ animals and so on for the subsequent pings.

Mathematics

A closed form function for this process can be derived as follows.

Define $P_n =$ unharassed population after ping n
Define $H =$ number of animals harassed in a ping with 100% unharassed population
$P_0 =$ local population

$$P_1 = P_0 - H$$

$$P_2 = P_1 - H\left(\frac{P_1}{P_0}\right)$$

...

$$P_n = P_{n-1} - H\left(\frac{P_{n-1}}{P_0}\right)$$

Therefore,

$$P_n = P_{n-1}\left(1-\left(\frac{H}{P_0}\right)\right) = P_{n-2}\left(1-\left(\frac{H}{P_0}\right)\right)^2 = ... = P_0\left(1-\left(\frac{H}{P_0}\right)\right)^n$$

Thus, the total number of harassments depends on the per-ping harassment rate in an unharassed population, the local population size, and the number of operation hours.

Local Population: Upper Bound on Harassments

As discussed above, Navy planners have confined period of sonar use to operation areas. The size of the harassed population of animals for an action depends on animal re-exposure, so uncertainty about the precise source path creates variability in the "harassable" population. Confinement of sonar use to a sonar operating area allows modelers to compute an upper bound, or worst case, for the number of harassments with respect to location uncertainty. This is done by assuming that there is a sonar transmitting from each point in the confined area throughout the action length.

NMFS has defined a 24 hour "refresh rate," or amount of time in which an individual can be harassed no more than once. Navy has determined that, in a 24 hour period, all sonar operations in the NSWC PCD Study Area transmit for a subset of that time (Table A-9).

Table A-9. Duration of Sonar Use During 24-hour Period

System	Longest continuous interval (in hrs)
AN/SQS-53/56 Kingfisher	0.5
Sub-bottom profiler (2-9 kHz)	2
REMUS SAS-LF	2
REMUS Modem	4
Sub-bottom profiler (2-16 kHz)	2
AN/SQQ-32	4
REMUS-SAS-LF	4
AN/BLQ-11	4
SAS-LF	4
AN/WLD-1 RMS-ACL	2
BPAUV Sidescan	4
TVSS	2
F84Y	2
BPAUV Sidescan	4
REMUS-SAS-HF	2
SAS-HF	2
AN/AQS-20	4
AN/WLD-11 RMS Navigation	2
BPAUV Sidescan	4

Creating the most conservative source position by assuming that a sonar transmits from each point in the SOA simultaneously can produce an upper bound on harassments for a single ping, but animal motion over the period in the above table can bring animals into range that otherwise would be out of the harassable population.

Animal Motion Expansion

Though animals often change course to swim in different directions, straight-line animal motion would bring the more animals into the harassment area than a “random walk” motion model. Since precise and accurate animal motion models exist more as speculation than documented fact and because the modeling requires an undisputable upper bound, calculation of the upper bound for SOCAL modeling areas uses a straight-line animal motion assumption. This is a conservative assumption.

For a circular area, the straight-line motion with initial random direction assumption produces an identical result to the initial fixed direction. Since the SOCAL Sonar Operating Areas (SOAs) are non-circular polygons, choosing the initial fixed direction as perpendicular to the longest diagonal produces greater results than the initial random direction. Thus, the product of the longest diagonal and the distance the animals move in the period of interest gives an overestimate of the expansion in SOCAL modeling areas due to animal motion. The SOCAL expansions use this overestimate for the animal-motion expansion.

Figure A-13 illustrates an example that illustrates the overestimation, which occurs during the second arrow.

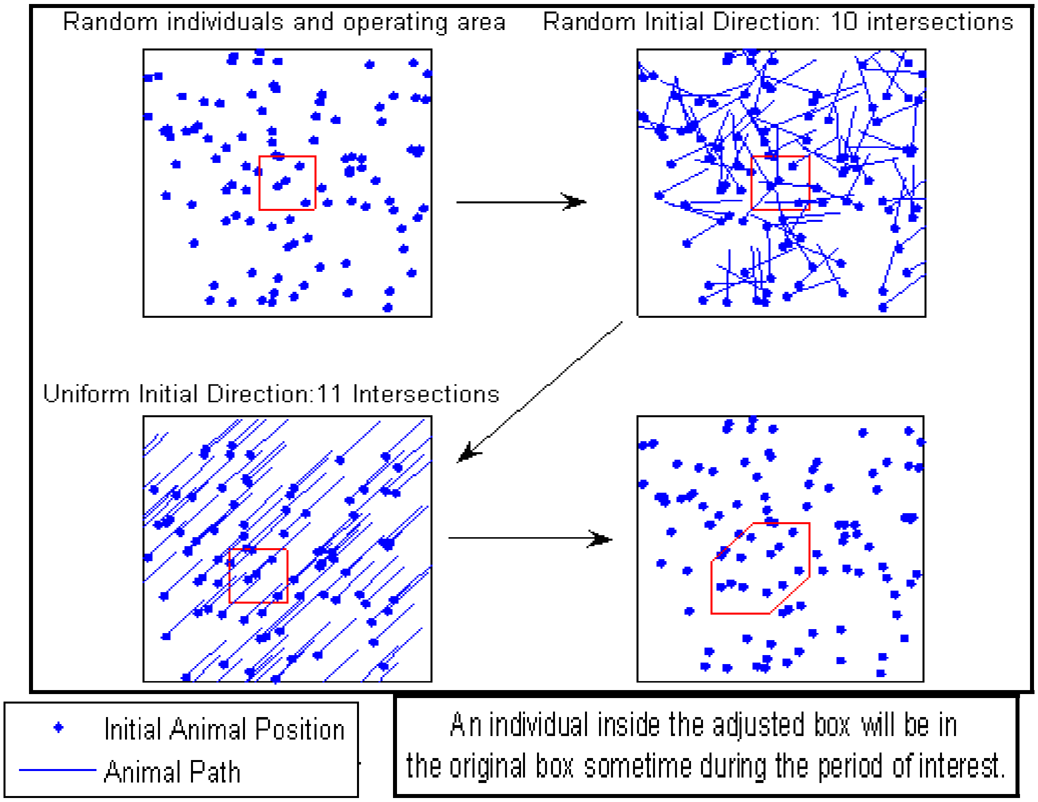


Figure A-13. Process of Overestimating Individuals Present in Area at Any Time.

Risk Function Expansion

The expanded area contains the number of animals that will enter the SOA over the period of interest. However, an upper bound on harassments must also include animals outside the area that would be affected by a source transmitting from the area's edge. A gross overestimation could simply include all area with levels greater than the risk function cutoff. In the case of Panama City, this would include all area within approximately 65 km from the edge of the adjusted box. This basic method would give a crude and inaccurately high upper bound, since only a fraction of the population is affected in much of that area. A more refined upper bound on harassments can be found by maintaining the assumption that a sonar is transmitting from each point in the adjusted box and calculating the expected ensonified area.

The expected lateral range from the edge of a polygon to the cutoff range can be expressed as,

$$\int_{0}^{L^{-1}(120dB)} D(L(r))dr \, ,$$

where D is the risk function with domain in level and range in probability, L is the SPL function with domain in range and range in level, and r is the range from the sonar operating area.

At the corners of the polygon, additional area can be expressed as

$$\frac{[\pi-\theta]\int_{0}^{L^{-1}(120dB)} D(L(r))rdr}{2\pi}$$

with D, L, and r as above, and θ the inner angle of the polygon corner, in radians.

For the risk function and transmission loss of the NSWC PCD Study Area, this method adds an area equivalent to expanding the boundaries of the adjusted box by four kilometers. The resulting shape, the adjusted box with a boundary expansion of 4 km, does not possess special meaning for the problem. But the number of individuals contained by that shape, as demonstrated above, is an overestimate of the number of harassments that would occur if sonars transmitted continuously from each point in the SOA over the exercise length, an upper bound on harassments for that operation.

Plots shown in Figure A-14 illustrate the growth of area for the sample case above. The shapes of the boxes are unimportant. The area after the final expansion, though, gives an upper bound on the "harassable," or unharassed population.

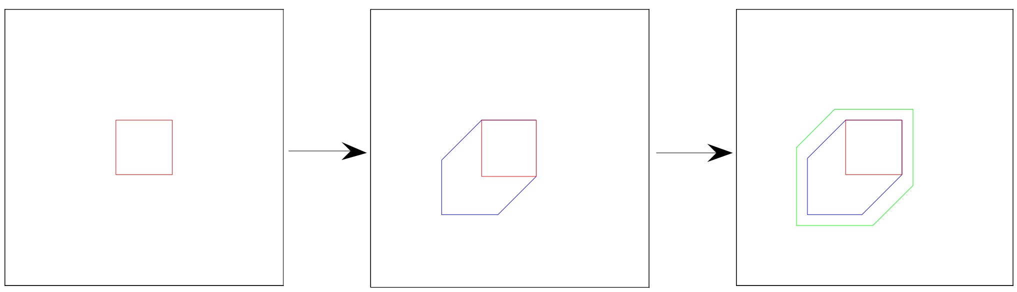


Figure A-14. Process of Expanding Area to Create Upper Bound of Harassments

Example Case

Consider a sample case from the NSWC PCD Study Area: for the most powerful source, the Kingfisher sonar, the expected summer rate of harassment for bottlenose dolphins is 0.000431261 harassments per ping. The exercise will transmit sonar pings for 0.5 hours in a 24 hour period, as given in the action table above, with 1200 pings per hour, a total of 0.5*1200=600 pings in a 24 hour period.

Area 2 has an area of approximately 9033 square kilometers and a largest side of 300 km. Adjusting this with straight-line (upper bound) animal motion of 5.5 kilometers per hour for 0.5 hours, animal motion adds 300*5.5*0.5= 825 square kilometers to the area. Using risk function response to calculate the expected range outside the SOA adds another 2475 square kilometers, bringing the total upper-bound of the affected area to 12,333 square km.

For this analysis, spinner dolphins have a density of 0.0011 animals per square kilometer in the OPAREA, so the upper bound number of bottlenose dolphins that can be affected by 53C sonar activity in the NSWC PCD Study Area during a 24 hour period is 12,333*0.00011 = 1.4 dolphins.

In the first ping, 0.000431261 bottlenose dolphins will be harassed. With the second ping, $0.000431261\left(\frac{1.4-0.000431261}{1.4}\right)=0.00043113$ bottlenose dolphins will be harassed. Using the formula derived above, after .5 hours of continuous operation, the remaining unharassed population is $P_{600}=P_0\left(1-\left(\frac{h}{P_0}\right)\right)^{600}=1.4\left(1-\left(\frac{0.000431261}{1.4}\right)\right)^{600}\approx 1.16$

So the harassed population will be 0.24 animals.

Contrast this with linear accumulation of harassments without consideration of the local population and the dilution of the unharassed population:

Harassments = 0.000431261*600= 0.26

The following graph illustrates the difference between the two approaches.

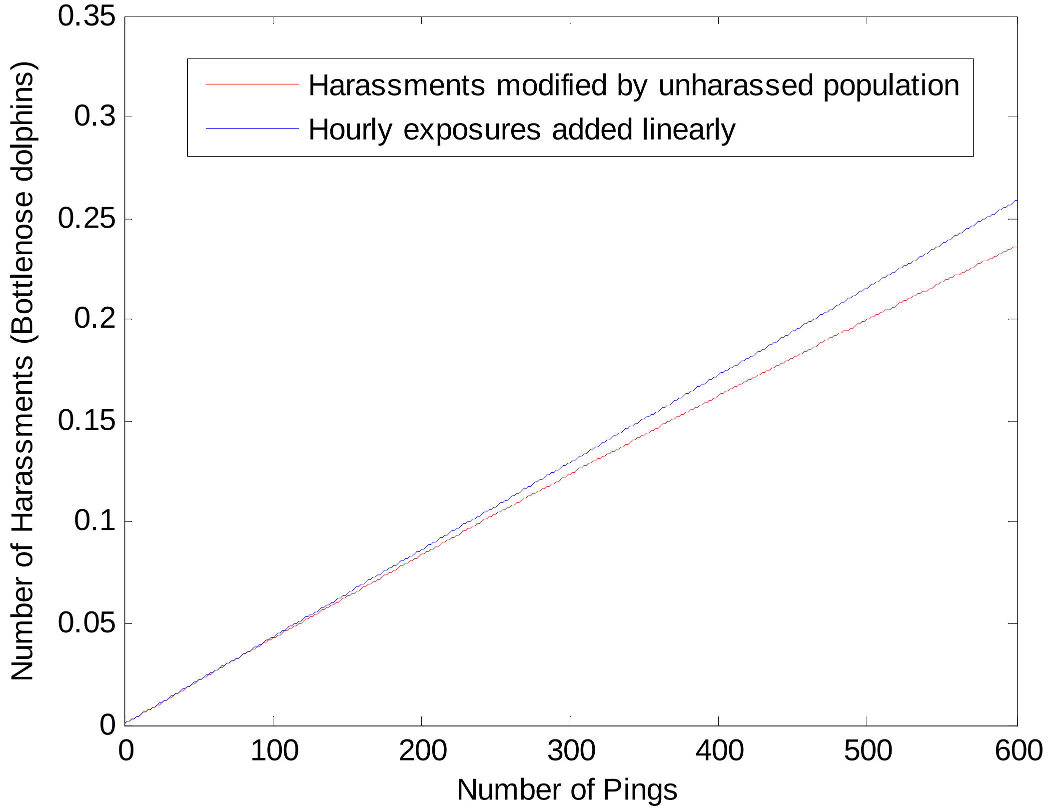


Figure A-15. Comparison of Harassments from Unlimited and Limited Populations

A.4.2 Land Shadow

The risk function considers harassment possible if an animal receives 120 dB sound pressure level, or above. In the NSWC PCD Study Area, this occurs as far away as 30 km, so over a large ”effect” area, sonar sound could, but does not necessarily, harass an animal. The harassment calculations for a general modeling case must assume that this effect area covers only water fully populated with animals, but in some portions of the OPAREA, land partially encroaches on the area, obstructing sound propagation.

As discussed in the introduction of “Additional Modeling Considerations …,” Navy planners do not know the exact location and transmission direction of the sonars at future times. These factors however, completely determine the interference of the land with the sound, or “land shadow,” so a general modeling approach does not have enough information to compute the land shadow effects directly. However, modelers can predict the reduction in harassments at any point due to land shadow for different pointing directions and use expected probability distribution of activity to calculate the average land shadow for operations in each SOA.

For Panama City, the land shadow is computed over a dense grid in each operations area, as shown in Figure A-16. The dense grid is shown by the near-continuous green dots. For illustrative purposes, every 25th point is shown as a red cross.

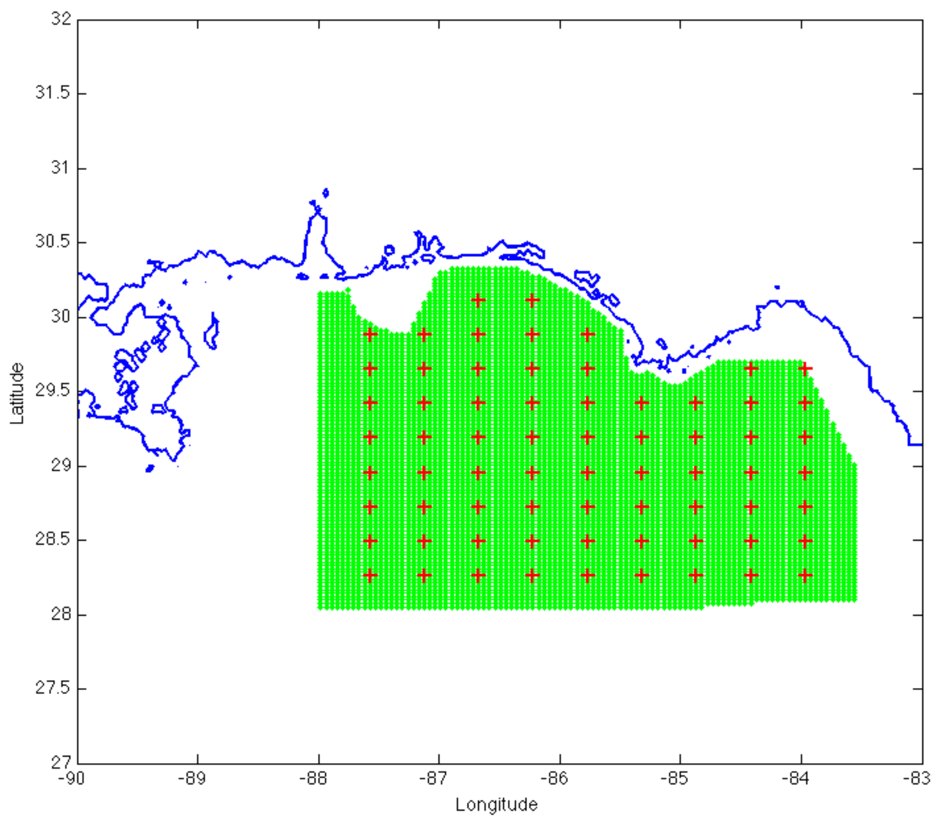


Figure A-16. Grid for The NSWC PCD Study Area.

For each grid point, the land shadow is computed by combining the distance to land and the azimuth coverage. The process finds all of the points within 30 km of the gridpoint. Figure A-17 gives an example. The red box is the operations area. The red X is one grid point, with the green circle corresponding to a radius of 30 km from the grid point.

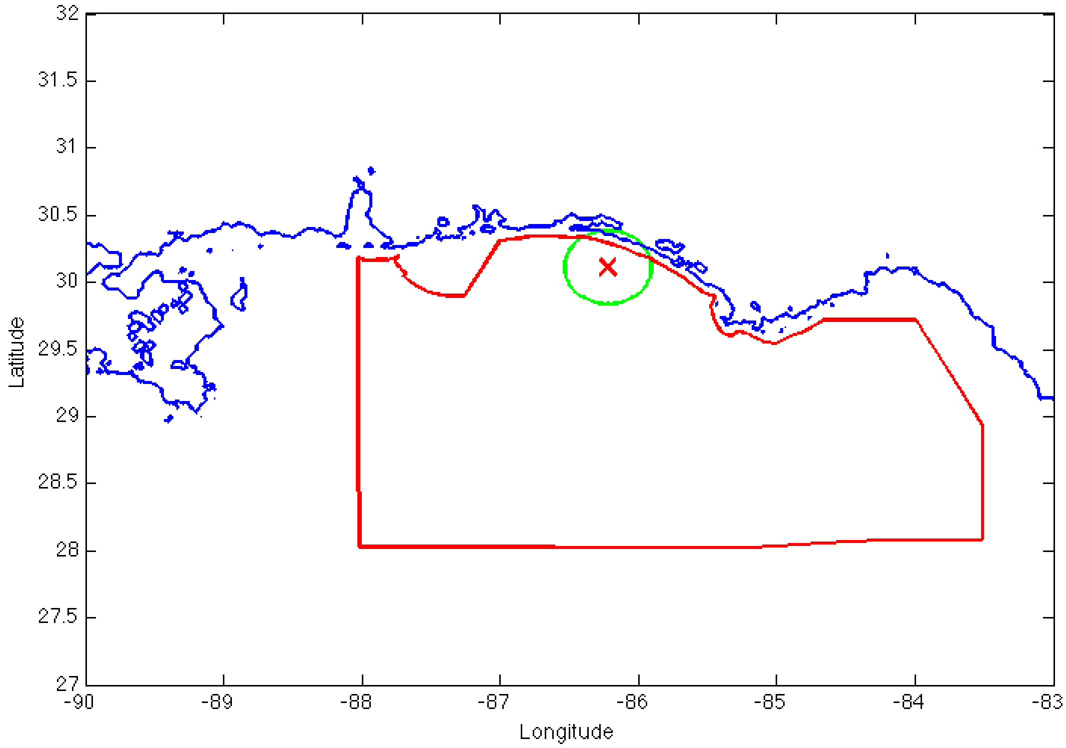


Figure A-17. Example of 30 km gridpoint.

For each of the coastal points that are within 30 km of the grid, the azimuth and distance is computed. In the computation, only the minimum range at each azimuth is computed. Figure A-18 shows the minimum range compared with the azimuth for the sample point. The nearest point at each azimuth (with 1^{o} spacing) to a sample grid point (red X) is shown by the green lines.

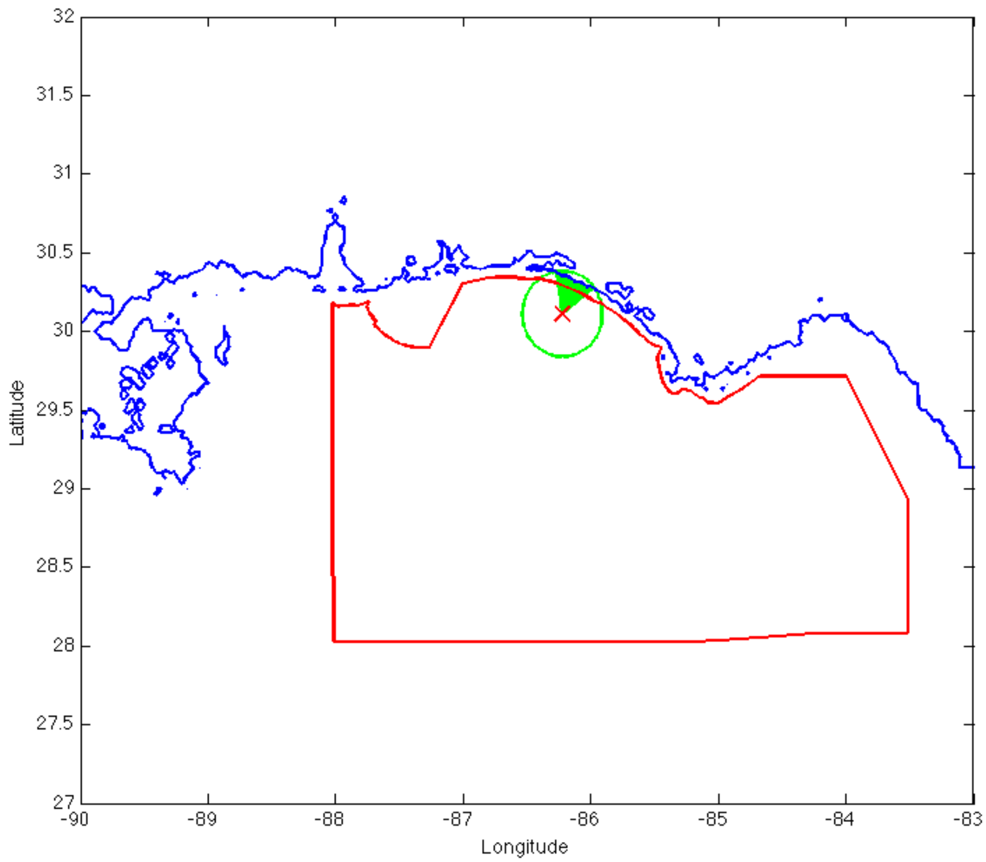


Figure A-18. Depiction of nearest point at each azimuth.

Now, the average of the distances to shore, along with the angular profile of land is computed (by summing the unique azimuths that intersect the coast) for each grid point. The values are then used to compute the land shadow for the grid points.

Computing the Land Shadow Effect at Each Grid Point

The effect of land shadow is computed by determining the levels, and thus the distances from the sources, that the harassments occur (Table A-10). Figure A-19 shows the percentage of behavioral harassments for every 5 degree band of received level from the Kingfisher.

Table A-10. Harassments at each Received Level Band from Kingfisher

Received Level (dB SPL)	Distance at which Levels Occur in OPAREA	Percent of Harassments Occurring at Given Levels
Below 140	5.9 km - 30 km	<< 1 %
140>Level>150	2.4 km – 5.9 km	2 %
150>Level>160	1.0 km – 2.5 km	16 %
160>Level>170	400 m – 1000 m	38%
170>Level>180	160 m – 400 m	28 %
180>Level>190	64 m - 160 km	13 %
Above 190	0 m – 64 m	3%

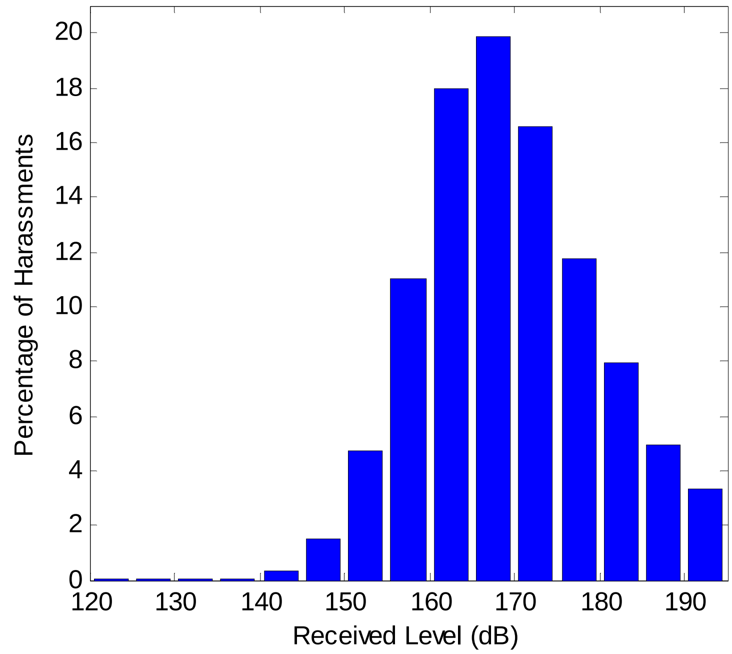


Figure A-19. Percentage of behavioral harassments from Kingfisher.

With the data used to produce the previous figure, the average effect reduction across season for a sound path blocked by land can be calculated. For example, since approximately 97 percent of harassments occur within 2 kilometers of the source, a sound path blocked by land at 2 kilometers will, on average, cause approximately 97 percent of the effect of an unblocked path (Figure A-20).

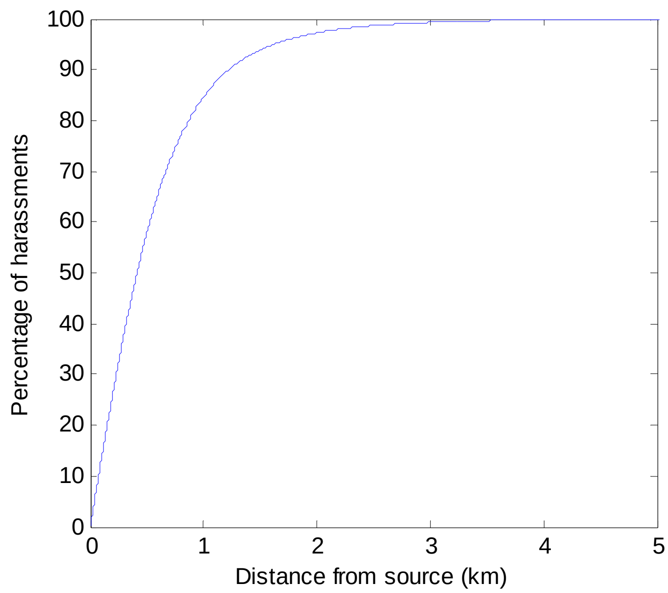


Figure A-20. Average Percentage of Harassments Occurring Within a Given Distance

As described above, the mapping process determines the angular profile of and distance to the coastline(s) from each grid point. The distance, then, determines the reduction due to land shadow when the sonar is pointed in that direction. The angular profile, then, determines the probability that the sonar is pointed at the coast.

Define θ_n = angular profile of coastline at point n in radians
Define r_n = mean distance to shoreline
Define A(r) = average effect adjustment factor for sound blocked at distance r

The land shadow at point n can be approximated by $A(r_n)\theta_n/(2\pi)$. The following plots give the land shadow reduction factor at each point in each SOA (Figure A-21). The white portions of the plot indicate the areas outside the NSWC PCD Study Area. The land shadow effects for most points burgundy or about 100 percent effect (0 percent reduction due to shadow).

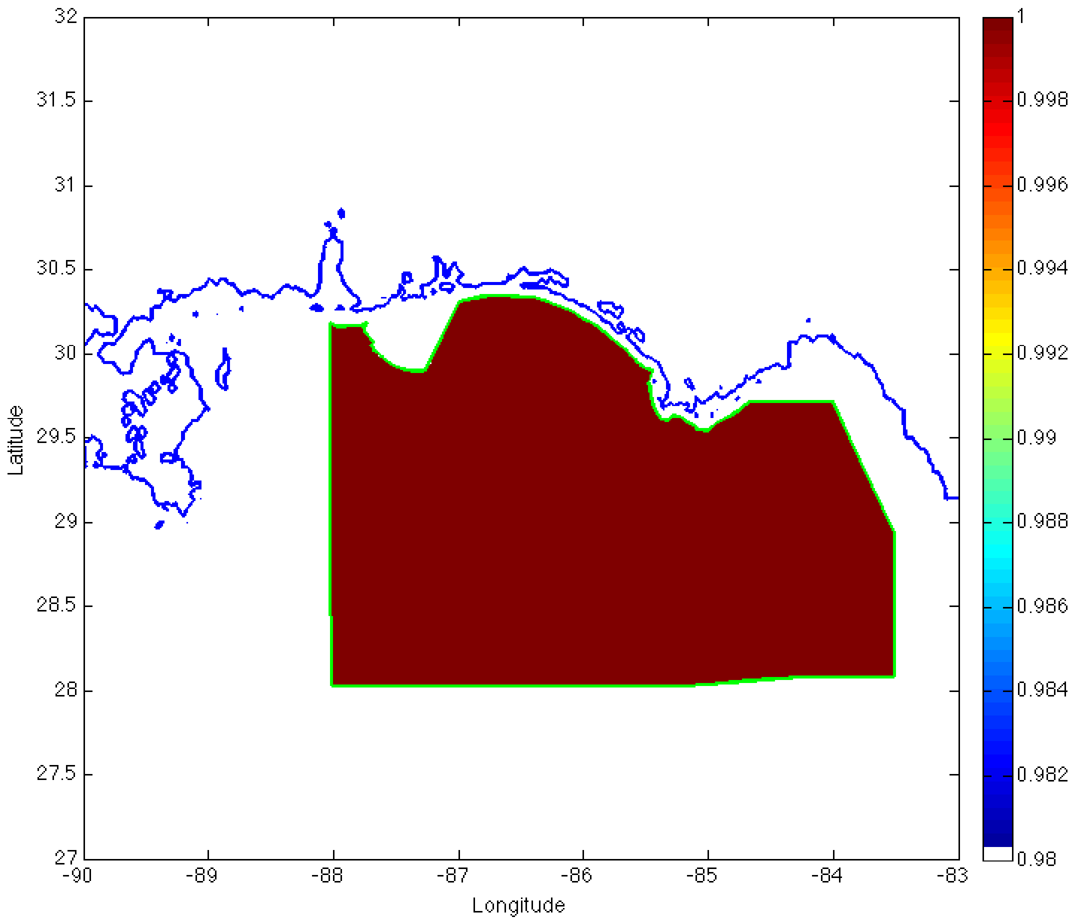


Figure A-21. Land Shadow Factor for the NSWC PCD Study Area.

To the naked eye, there is no portion of the NSWC PCD Study Area that has less than negligible effect. The following plot zooms in on part of the area to make visible a sliver of area that has a small reduction due to land shadow (Figure A-22).

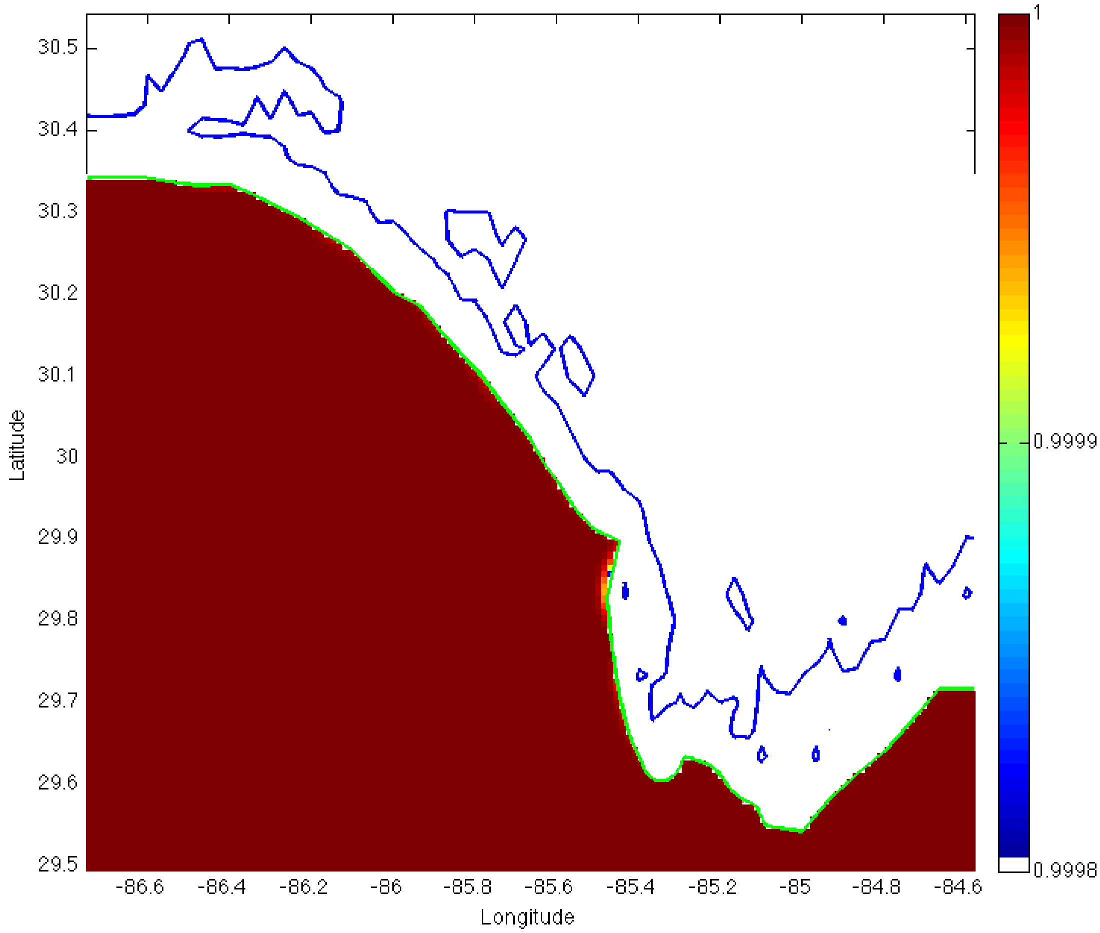


Figure A-22. Zoom in on the NSWC PCD Study Area.

Note the scaling on Figure A-22: even for this sliver, the reduction due to land shadow is less than 0.01 percent. On average, across the OPAREA, the reduction in effect due to land shadow is zero.

A.5 HARASSMENTS

This section defines the animal densities and their depth distributions for the NSWC PCD Study Area. A short discussion is presented on how harassments are calculated from the ensonification volumes, two dimensional animal densities, and animal depth distributions.

A.5.1 Marine Mammal Density and Depth Distribution for NSWC PCD Study Area, Eastern Gulf of Mexico

Marine mammal species occurring in the eastern Gulf of Mexico (GOM) include baleen whales (mysticetes), toothed whales (odontocetes), and sirenians (manatees). Baleen and toothed whales, collectively known as cetaceans, spend their entire lives in the water and spend most of the time (>90 percent for most species) entirely submerged below the surface. When at the surface, cetacean bodies are almost entirely below the water's surface, with only the blowhole exposed to allow breathing. This makes cetaceans difficult to locate visually and also exposes them to underwater noise, both natural and anthropogenic, essentially 100 percent of the time because their ears are nearly always below the water's surface. Manatees also spend their entire lives in the water, and usually raise only the nostrils above the water's surface to breathe, which also exposes them to underwater noise essentially 100 percent of the time.

For the purposes of this analysis, the Department of the Navy (DON) has adopted a conservative approach to underwater noise and marine mammals:

Cetaceans – assume 100 percent of time is spent underwater and therefore exposed to noise.

Sirenians – assume 100 percent of time is spent underwater and therefore exposed to noise.

Table A-11 provides depth information for each of the species in the NSWC PCD Study Area. Dive profiles and foraging characteristics do not significantly differ among different geographic regions. Furthermore, information for some species is limited and therefore, the best available information was used.

MYSTICETES

Blue whale, *Balaenoptera musculus* – Extralimital

There is no abundance or density estimate.

Fin whale, *Balaenoptera physalus* – Extralimital

There is no abundance or density estimate.

Sei whale, *Balaenoptera borealis* – Extralimital

There is no abundance or density estimate.

Bryde's whale, *Balaenoptera edeni*

Bryde's whales are found mainly in tropical and temperate waters, in areas of high productivity where water temperature is at least 16.3°C (Reeves et al., 2002; Kato, 2002). The current population estimate for the northern GOM stock of Bryde's whales is 40 animals (CV = 0.61) (Mullin and Fulling, 2004). They are the most frequently observed baleen whale in the GOM and, although sightings are not numerous, they are geographically predictable (Figure A-23). Bryde's whale sightings from 1992-2004 nearly all occurred in the northeastern part of the GOM, particularly along the Florida Escarpment (Maze-Foley and Mullin, 2006; K. Mullin, pers. comm.; Table A-12; Figure A-23). Bryde's whales were most often sighted in small groups (mean=2.0, range 1-5 animals), with sea surface temperatures from 21.5-25.9°C, and at depths ranging from 199-302 m (mean = 226.3 m) during vessel surveys conducted from 1991-2001 along the shelf edge and oceanic northern GOM (Maze-Foley and Mullin, 2006). Most sightings (60 percent) from 1992-2004 occurred in waters >200 m deep, with all sightings recorded near the 200 m contour. Davis et al. (2000) calculated Bryde's whale density (0.00035/km^2) for the 100-2,000 m depth regime in the eastern GOM, and most of those sightings were just seaward of the 200 m contour (Maze-Foley and Mullin, 2006) depth regime. Density for the 200-2,000 m depth regime in the eastern GOM (Mullin and Fulling, 2004) was higher (0.0006/km^2), and is used here. Extrapolating this density resulted in an abundance of 15 whales for the entire OPAREA. This abundance was divided by the area in which Bryde's whales are expected to occur, based on 12 years of sighting data (8,560 km^2; see Figure A-23), resulting in a density of 0.0018/km^2. This density is applicable to only 11 percent of the entire NSWC PCD Study Area (8,560 km^2/ 77,938 km^2).

Bryde's whales feed on pelagic schooling fish, small crustaceans including euphausiids and copepods, and cephalopods (Kato, 2002). Feeding appears to be regionally different. Off South Africa, the inshore form feeds on epipelagic fish while the offshore form feeds on mesopelagic fish and euphausiids (Best, 1977; Bannister, 2002). Stomach content analysis from whales in the southern Pacific and Indian oceans indicated that most feeding apparently occurred at dawn and dusk, and were primarily euphausiids (Kawamura, 1980). There have been no depth distribution data collected on Bryde's whales. In lieu of depth data, minke whale depth distribution percentages will be extrapolated to Bryde's whales. Minke whales feed on small schooling fish and krill. The only depth distribution data for this species are reported from a study on daily energy expenditure conducted off northern Norway and Svalbard (Blix and Folkow, 1995). The limited depth information available (from Figure 2 in Blix and Folkow, 1995) is representative of a 75-min diving sequence where the whale was apparently searching for capelin, then foraging, then searching for another school of capelin. Search dives were mostly to ~20 m, while foraging dives were to 65 m. Based on this very limited depth information, rough estimates for percent of time at depth are as follows: 53 percent at <20 m and 47 percent at 20-65 m.

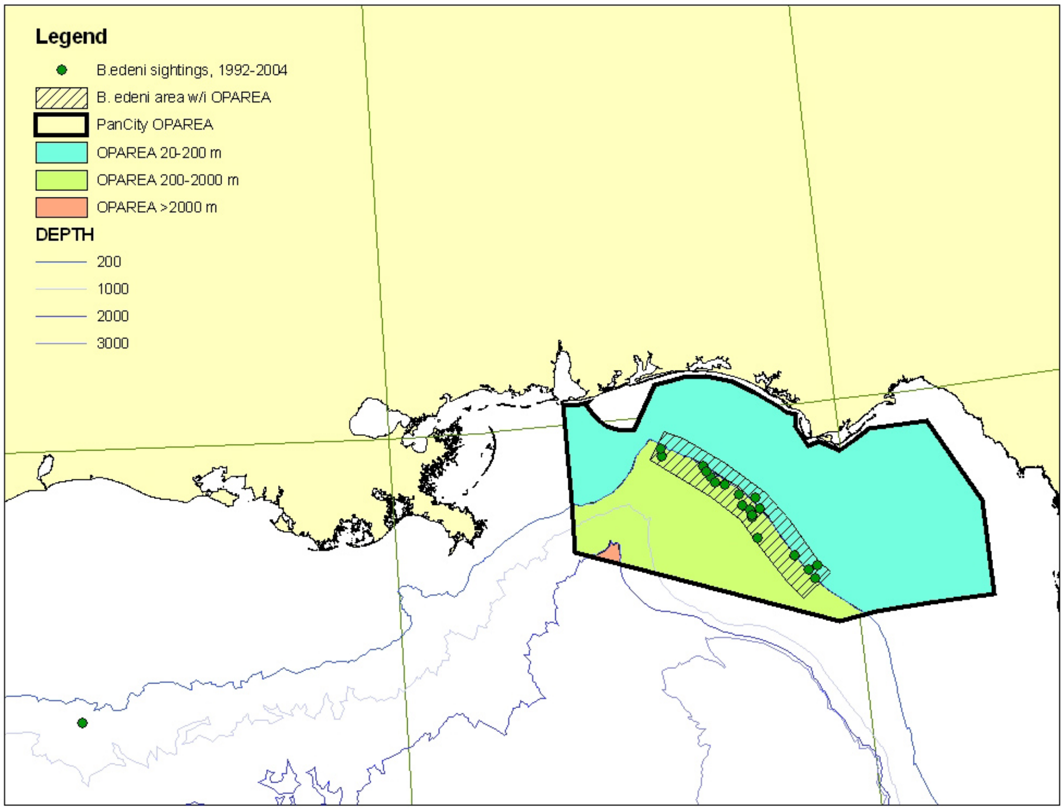


Figure A-23. Bryde's whale sightings from and area within the NSWC PCD Study Area in which Bryde's whales are likely to occur and for which density was calculated.

Table A-12. Summary of Bryde's whale sightings from 1992-2004

YearMonthDay	Lat	Lon	Depth(m)	SST	GroupSize
19920422	29.5303	-86.5270	182	21.9	4
19920422	28.6425	-85.6377	192	21.5	1
19920601	27.5613	-93.4997	256	25.9	2
19940428	29.0250	-86.0545	235	24.3	1
19940905	29.0952	-86.0613	221	28.8	1
19960508	28.4987	-85.4990	197	23.0	2
19960606	29.6535	-86.9750	206	28.0	1
19960606	29.7218	-86.9853	206	28.0	4
19970509	29.1425	-86.1433	221	23.2	2
19990423	29.4268	-86.4610	224	22.1	2
19990423	29.3698	-86.4212	230	22.2	1
20000420	29.4757	-86.5045	184	22.4	3
20000420	29.0453	-86.0438	212	23.1	2
20000512	28.4187	-85.4288	192	27.0	2
20010511	28.8358	-86.0125	272	25.1	1
20040505	29.1980	-85.9948	173	21.7	2
20040505	28.5315	-85.3972	175	22.9	1
20040520	29.0985	-85.9595	186	26.3	1
20040520	29.2390	-86.1663	213	26.2	1
20040520	29.3390	-86.3088	219	26.3	3

Source: Data obtained from K. Mullin, NMFS-SEFSC

Minke whale, *Balaenoptera acutorostrata* - Extralimital

There is no abundance or density estimate.

Humpback whale, *Megaptera novaeangliae* - Extralimital

There is no abundance or density estimate.

North Atlantic right whale, *Eubalaena glacialis* - Extralimital

There is no abundance or density estimate.

ODONTOCETES

Sperm whale, *Physeter catodon*

Sperm whales are most often found in deep water, near submarine canyons, and along the edges of banks, over continental slopes and particularly in regions of upwelling and high primary productivity (Whitehead, 2002; Reeves et al., 2002). In the GOM, the sperm whale is the most common large cetacean, with the greatest number of recent and historical sightings occurring beyond the edge of the continental shelf (Jefferson and Schiro, 1997; Mullin and Fulling, 2004; Maze-Foley and Mullin, 2006). They appear to prefer steep rather than shallow depth gradients and areas of confluence and high estimated biomass. Results from a multiyear study on the movements and habitat use of sperm whales in the northern GOM (Sperm Whale Seismic Study [SWSS]; Jochens et al., 2006) demonstrated the importance of the region offshore of the mouth of the Mississippi River, east of the NSWC PCD Study Area, which appears to be an especially important year round area for females and immatures. Satellite tag studies during the SWSS indicate movements generally along the shelf break (700–1,000 m [2,297-3,281 ft] depth) throughout the GOM, with some animals using deeper oceanic waters. Estimated abundance for the GOM from surveys conducted from 1996-2001 was 1,349 (CV=0.23) (Mullin and Fulling, 2004). Density of sperm whales in the eastern GOM is available for two depth regimes: 0.0015/km^2 for 200–2,000 m (656-6,562 ft) and 0.0037/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0005/km^2.

Unlike other cetaceans, there is a preponderance of dive information for this species, most likely because it is the deepest diver of all cetacean species so generates a lot of interest. Sperm whales feed on large and medium-sized squid, octopus, rays and sharks on or near the ocean floor. Some evidence suggests that they do not always dive to the bottom of the sea floor (likely if food is elsewhere in the water column), but that they do generally feed at the bottom of the dive. Davis et al. (2007) report that dive-depths (100–500 m [328-1,640 ft]) of sperm whales in the Gulf of California overlapped with depth distributions (200–400 m [656-1,312 ft]) of jumbo squid, based on data from satellite-linked dive recorders placed on both species, particularly during daytime hours. Their research also showed that sperm whales foraged throughout a 24-hour period, and that they rarely dove to the sea floor bottom (>1,000 m [3,281 ft]). The most consistent sperm whale dive type is U-shaped, whereby the whale makes a rapid descent to the bottom of the dive, forages at various velocities while at depth (likely while chasing prey) and then ascends rapidly to the surface. Amano and Yoshioka (2003) attached a tag to a female sperm whale near Japan in an area where water depth was 1,000–1,500 m (3,281-4,921 ft). Based on values in Amano and Yoskioka (2003) for dives with active bottom periods, the total mean dive sequence was 45.9 min (mean surface time plus dive duration). Mean post dive surface time divided by total time (8.5/45.9), plus time at surface between deep dive sequences yields a percentage of time at the surface (<10 m [33 ft]) of 31 percent. Mean bottom time divided by total time (17.5/45.9) and adjusted to include the percent of time at the surface between dives, yields a percentage of time at the bottom of the dive (in this case >800 m [2,624 ft] as the mean maximum depth was 840 m [2,756 ft]) of 34 percent. Total time in the water column descending or ascending equals duration of dive minus bottom time (37.4-17.5) or approximately 20 minutes. Assuming a fairly equal descent and ascent rate and a fairly consistent descent/ascent rate over depth, we assume 10 minutes each for descent and ascent and equal amounts of time in each depth gradient in either direction. Therefore, 0–200 m (0–656 ft) = 2.5 minutes one direction (which correlates well with the descent/ascent rates provided) and therefore 5 minutes for both directions. The same assumption is made for 201–400 m (659–1,312 ft), 401–600 m (1,316–1,969 ft) and 601–800 m (1,972–2,624 ft). Therefore, the depth distribution for sperm whales based on information in the Amano paper is: 31 percent in <10 m (33 ft), 8 percent in 10–200 m (33-656 ft), 9 percent in 201-400 m (659-1,312 ft), 9 percent in 401–600 m (1,316–1,969 ft), 9 percent in 601–800 m (689–1,312 ft) and 34 percent in >800 m (1,312 ft). These percentages derived from data in Amano and Yoshioka (2003) are in fairly close agreement with those derived in Watwood et al. (2006) for sperm whales in the Ligurian Sea, Atlantic Ocean and GOM.

Kogia sp, including pygmy (*Kogia breviceps*) and dwarf (*Kogia sima*) sperm whales

Pygmy (*Kogia breviceps*) and dwarf (*Kogia sima*) sperm whales are difficult to differentiate at-sea, and are therefore often recorded as *Kogia* sp. during survey efforts. The distribution of both species is generally temperate to tropical and probably seaward of the continental shelf (McAlpine, 2002; Reeves et al., 2002); there is some evidence that dwarf sperm whales prefer somewhat warmer waters than do pygmy sperm whales. *Kogia* have been sighted throughout the GOM seaward if the 200 m (656 ft) contour (Maze-Foley and Mullin, 2006) and Baumgartner et al. (2001) found them predominantly along the upper continental slope in areas of high epipelagic zooplankton biomass. The most recent stock estimate for the GOM stock of *Kogia* sp. was 742 (CV = 0.29) (Mullin and Fulling, 2004). Density of *Kogia* sp. in the eastern GOM is available for two depth regimes: 0.0015/km^2 for 200–2000 m (656-6,562 ft) and 0.0021/km^2 for >2000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0005/km^2.

There are no depth distribution data for this species. An attempt to record dive information on a rehabbed pygmy sperm whale failed when the TDR package was never recovered (Scott et al., 2001). Prey preference, based on stomach content analysis from Atlantic Canada (McAlpine et al., 1997) and New Zealand (Beatson, 2007), appears to be mid and deep water cephalopods, crustaceans and fish. There is some evidence that *Kogia* may use suction feeding and feed at or near the bottom. They may also take advantage of prey undergoing vertical migrations to shallower waters at night (Beatson, 2007). In lieu of any other information, Blainville's beaked whale depth distribution data will be extrapolated to pygmy sperm whales, since the two species appear to have similar prey preferences and are closer in size than either is to sperm or Cuvier's beaked whales. Blainville's undertake shallower non-foraging dives in-between deep foraging dives (DFDs). Blainville's beaked whale depth distribution data, taken from Tyack et al. (2006) and summarized in greater depth later in this document is: 26 percent at <2 m (6.6 ft), 41 percent at 2–71 m (6.6–233 ft), 2 percent at 72–200 m (236–656 ft), 4 percent at 201–400 m (659–1,312 ft), 4 percent at 401-600 m (1,316-1,969 ft), 4 percent at 601-835 m (1,972-2,740 ft) and 19 percent at >838 m (2,749 ft).

Cuvier's beaked whale, *Ziphius cavirostris*

Cuvier's beaked whale has the widest distribution of all beaked whales, and occurs in all oceans. It is most often found in deep offshore waters, and appears to prefer slope waters with steep depth gradients (Heyning, 2002). As with most beaked whales, Cuvier's are fairly cryptic at-sea and are therefore difficult to sight and identify. The best abundance estimate for Cuvier's beaked whales for the GOM stock, based on vessel surveys conducted from 1996 to 2001, is 95 (CV = 0.47) (Mullin and Fulling, 2004). Density of Cuvier's beaked whales in the eastern GOM is available for two depth regimes: 0.0004/km^2 for 200–2000 m (656-6,562 ft) and 0.0001/km^2 for >2000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0001/km^2.

Cuvier's feed on meso-pelagic or deep water benthic organisms, particularly squid (Heyning, 2002). Stomach content analysis indicates that they take advantage of a larger range of prey species than do other deep divers (e.g., Santos et al., 2001; Blanco and Raga, 2000). Cuvier's, like other beaked whales, are likely suction feeders based on the relative lack of teeth and enlarged hyoid bone and tongue muscles. Foraging dive patterns appear to be U-shaped, although inter-ventilation dives are shallower and have a parabolic shape (Baird et al., 2006a). Depth distribution studies in Hawaii (Baird et al., 2005a; Baird et al., 2006a) found that Cuvier's undertook three or four different types of dives, including intermediate (to depths of 292-568 m [958-1,864 ft]), deep (>1,000 m [3,281 ft]) and short-inter-ventilation (within 2-3 m [6.6-9.9 ft] of surface); this study was of a single animal. Studies in the Ligurian Sea indicated that Cuvier's beaked whales dived to >1,000 m (3,281 ft) and usually started "clicking" (actively searching for prey) around 475 m (Johnson et al., 2004; Soto et al., 2006). Clicking continued at depths and ceased once ascent to the surface began, indicating active foraging at depth. In both locations, Cuvier's spent more time in deeper water than did Blainville's beaked whale, although maximum dive depths were similar. There was no significant difference between day and night diving indicating that preferred prey likely does not undergo vertical migrations.

Dive information for Cuvier's was collected in the Ligurian Sea (Mediterranean) via DTAGs on a total of seven animals (Tyack et al., 2006) and, despite the geographic difference and the author's cautions about the limits of the data set, the Ligurian Sea dataset represents a more complete snapshot than that from Hawaii (Baird et al., 2006a). Cuvier's conducted two types of dives – U-shaped DFD and shallow duration dives. Dive cycle commenced at the start of a DFD and ended at the start of the next DFD, and included shallow duration dives made in between DFD.

Mean length of dive cycle = 121.4 min (mean DFD plus mean Inter-deep dive interval)
Number of DFD recorded = 28
Mean DFD depth = 1,070 m (3,510 ft) (range 689–1888 m [2,260–6,194 ft)
Mean length DFD = 58.0 min
Mean Vocal phase duration = 32.8 min
Mean inter-deep dive interval = 63.4 min
Mean shallow duration dive = 221 m (725 ft) (range 22-425 m [72-1,394 ft)
Mean # shallow duration dives per cycle = 2 (range 0–7)
Mean length of shallow duration dives = 15.2 min

Total time at surface (0–2 m [0–6.6 ft) was calculated by subtracting the mean length of DFD and two shallow duration dives from the total dive cycle (121.4 - 58.0 – 30.4 = 33 min). Total time at deepest depth was taken from the Vocal phase duration time, as echolocation clicks generally commenced when animals were deepest, and was 32.8 min. The amount of time spent descending and ascending on DFDs was calculated by subtracting the mean Vocal phase duration time from the mean total DFD (58.0 - 32.8 = 25.2 min) and then dividing by five (number of 200 m [656 ft] depth categories between surface and 1070 m [3,510 ft]) which equals approximately five min per 200 m (656 ft). The five-minute value was applied to each 200 m (656 ft) depth category from 400–1070 m (1,312-3,510 ft); for the 2-220 m (6.6-722 ft) category, the mean length of shallow duration dives was added to the time for descent/ascent (30.4 + 5 = 35.4 min). Therefore, the depth distribution for Cuvier's beaked whales based on best available information from Tyack et al. (2006) is: 27 percent at <2 m, 29 percent at 2-220 m (6.6-722 ft), 4 percent at 221-400 m (725-1,312 ft), 4 percent at 401-600 m (1,316-1,969 ft), 4 percent at 601-800 m (1,972-2,624 ft), 5 percent at 801-1070 m (2,627-3,510 ft) and 27 percent in >1,070 m (3,510 ft).

UNIDENTIFIED BEAKED WHALES, FAMILY *ZIPHIIDAE*

This category includes all beaked whale species within the family Ziphiidae, and generally includes sightings that are known to be beaked whales but which cannot be distinguished further than family level. Density of Ziphiid whales in the eastern GOM is available for only the deepest depth regimes: 0.0007/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). When this density was extrapolated to the entire OPAREA, the density was 0.000003/km^2.

Ziphiids feeds primarily on mesopelagic squid and some fish, with most prey likely caught at >200 m (656 ft) (Pitman, 2002b). Most are believed to be suction feeders. There are no depth distribution data for the entire family, however good dive information has been collected for a few species. The depth distribution for Cuvier's beaked whales will be extrapolated to Ziphiids.

Beaked whale species, *Mesoplodon* sp, including Gervais', *Mesoplodon europaeus*, Sowerby's, *M. bidens*, and Blainville's, *M. densirostris*

Gervais' beaked whales occur in warm temperate and tropical waters of the North Atlantic (Reeves et al., 2002; Pitman, 2002b). Sowerby's beaked whales are distributed in the temperate North Atlantic, and are known from the GOM based on a single stranding in 1984 (Bonde and O'Shea, 1989). Blainville's are distributed circumglobally in tropical and warm temperate waters. Very little is known about the behavior of any of these species, as they are cryptic and difficult to sight at sea. Unidentified Mesoplodonts have been sighted during most vessel cruises conducted in the GOM, but very few can be identified to species (with the exception of *M. densirostris*). Density of Mesoplodonts in the eastern GOM is available for two depth regimes: 0.0003/km^2 for 200–2,000 m (656-6,562 ft) and 0.0001/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0001/km^2.

Mesoplodon sp. feeds primarily on mesopelagic squid and some fish, with most prey likely caught at >200 m (656 ft) (Pitman, 2002b). Like other beaked whales, they are believed to be suction feeders. There are no depth distribution data for *Mesoplodon* species as a group, however good dive information has been collected on *Mesoplodon densirostris* in Hawaii (Baird et al., 2006a; 2005a) and the Canary Islands (Tyack et al., 2006). Dive information for Blainville's collected in the Canary Islands via DTAGs on a total of eight animals (Tyack et al., 2006) represents a more complete snapshot than that from Hawaii (Baird et al., 2006a). Blainville's conducted two types of dives – U-shaped DFD and shallow duration dives. Dive cycle commenced at the start of a DFD and ended at the start of the next DFD, and included shallow duration dives made in between DFD.

Mean length of dive cycle = 138.8 min (mean DFD plus mean Inter-deep dive interval)
Number of DFD recorded = 16
Mean DFD depth = 835 m (2,740 ft) (range 640–1251 m [2,100–4,104 ft])
Mean length DFD = 46.5 min
Mean Vocal phase duration = 26.4 min
Mean inter-deep dive interval = 92.3 min
Mean shallow duration dive = 71 m (233 ft) (range 20–240 m [66-787 ft])
Mean # shallow duration dives per cycle = 6 (range 1-12)
Mean length of shallow duration dives = 9.3 min

Total time at surface (0–2 m [0–6.6 ft]) was calculated by subtracting the mean length of DFD and six shallow duration dives from the total dive cycle (138.8 – 46.5 – 55.8 = 36.5 min). Total time at mean deepest depth was taken from the Vocal phase duration time, as echolocation clicks generally commenced when animals were deepest, and was 26.4 min. The amount of time spent descending and ascending on DFDs was calculated by subtracting the mean Vocal phase duration time from the mean total DFD (46.5 – 26.4 = 20.1 min) and then dividing by 12 (# of 70 m [230 ft] depth categories between surface and 838 m [2,749 ft]), which equals 1.7 min per 70 m (230 ft). The 1.7 min value was applied to each 70 m (230 ft) depth category from 72-838 m (236-2,749 ft); for the 2-71 m (6.6-233 ft) category, the mean length of shallow duration dives was added to the time for descent/ascent (55.8 + 1.7 = 57.5 min). Therefore, the depth distribution for Blainville's beaked whales (and applicable to *Mesoplodon* sp) based on best available information from Tyack et al. (2006) is: 26 percent at <2 m (6.6 ft), 41 percent in 2-71 m (6.6=233 ft), 2 percent at 72-200 m (236-656 ft), 4 percent at 201–400 m (659–1,312 ft), 4 percent at 401-600 m (1,316-1,969 ft), 4 percent at 601-835 m (1,972-2,740 ft), and 19 percent at >835 m (2,740 ft).

Killer whale, *Orcinus orca*

Killer whales are one of the most widely distributed mammal species in the world and are found in all oceans (Ford, 2002). They have been sighted throughout the GOM, generally in waters >200 m deep (Maze-Foley and Mullin, 2006; Jefferson and Schiro, 1997). The most recent abundance estimate for the northern GOM stock is 133 (CV = 0.49) (Mullin and Fulling, 2004). Density of killer whales in the eastern GOM is available only for the >2000 m depth regime: 0.0005/km^2 (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.000002/km^2.

Killer whales feed on a variety of prey, including salmon, herring, cod, tuna and cephalopods (Ford, 2002). "Transient" stocks of killer whales feed on other marine mammals, including other whales, pinnipeds (e.g., London, 2006) and sea otters (e.g., Estes et al., 1998). Diving studies on killer whales have been undertaken mainly on "resident" (fish-eating) killer whales in Puget Sound and may not be applicable across all populations of killer whales. Diving is usually related to foraging, and mammal-eating killer whales may display different dive patterns. Killer whales in one study (Baird et al., 2005b) dove as deep as 264 m (866 ft), and males dove more frequently and more often to depths >100 m (328 ft) than females, with fewer deep dives at night. Dives to deeper depths were often characterized by velocity bursts which may be associated with foraging or social activities. Using best available data from Baird et al. (2003a), it would appear that killer whales spend approximately 4 percent of time at depths >30 m (98 ft) and 96 percent of time at depths 0–30 m (0–98 ft).

False killer whale, *Pseudorca crassidens*

False killer whales are found in tropical to warm temperate waters, with well known populations near Japan and in the eastern tropical Pacific (Baird, 2002a). They are mainly pelagic but will occur close to shore near oceanic islands. Distribution in the GOM has been mainly in oceanic waters. The most recent estimate for the northern GOM stock is 1,038 (CV = 0.71) (Mullin and Fulling, 2004). Density of false killer whales in the eastern GOM is available for two depth regimes: 0.0053/km^2 for 200–2000 m (656-6,562 ft) and 0.0037/km^2 for >2000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0017/km^2.

False killer whales feed on oceanic fish and squid, and have been known to prey on smaller marine mammals (Baird, 2002a; Koen Alonso et al., 1999; Santos and Haimovici, 2001).

The only study conducted on diving of false killer whales in Hawaii has not been published in any detail (Ligon and Baird, 2001), but an abstract provide limited information. False killer whales did not dive deep and instead recorded maximum dives of 22, 52, and 53 m (72, 171, and 174 ft) in near-shore Hawaiian waters. In lieu of other information, the depth distribution for killer whales will be extrapolated to this species: 4 percent of time at depths >30 m (98 ft) and 96 percent of time at depths 0–30 m (0–98 ft).

Pygmy killer whale, *Feresa attenuata*

Pygmy killer whales are known primarily from tropical to sub-tropical waters, and sightings in the GOM most commonly occur in oceanic waters (Donahue and Perryman, 2002; Maze-Foley and Mullin, 2006; Jefferson and Schiro, 1997). The most recent abundance estimate for the northern GOM stock is 408 (CV = 0.60) (Mullin and Fulling, 2004). Density of pygmy killer whales in the eastern GOM is available for only the deepest depth regime: 0.0022/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.00001/km^2.

Pygmy killer whales feed on cephalopods, small fish and small delphinids (Donohue and Perryman, 2002; Santos and Haimovici, 2001). There have not been any studies of diving patterns specific to this species. In lieu of other information, the depth distribution for killer whales will be extrapolated to this species: 4 percent of time at depths >30 m (98 ft) and 96 percent of time at depths 0–30 m (0–98 ft).

Short-finned pilot whale, *Globicephala macrorhynchus*

This species is known from tropical and warm temperate waters, and is found primarily near continental shelf breaks, slope waters and areas of high topographic relief (Olson and Reilly, 2002). Recent and historic distribution in the GOM has been mostly on the continental slope in waters >200 m (Maze-Foley, 2006; Jefferson and Schiro, 1997) and most sightings have been south and west of the Mississippi River Delta (Waring et al., 2007). The most recent abundance estimate for the entire GOM, from vessel surveys conducted 1996-2001, was 2,388 (CV = 0.48) (Mullin and Fulling, 2004). Based on those surveys, there is no density available for short-finned pilot whales in the eastern GOM. Density is zero for the eastern GOM.

Melon-headed whale, *Peponocephala electra*

Melon-headed whales are found worldwide in deep, offshore tropical and subtropical waters. Their current and historical distribution in the GOM is largely west of the Mississippi River Delta (Waring et al., 2007); there has been a single sighting in the eastern GOM. The most recent abundance estimate for the entire GOM, from vessel surveys conducted 1996-2001, was 3,451 (Mullin and Fulling, 2004). Based on those surveys, there is no density available for short-finned pilot whales in the eastern GOM. Density is zero for the eastern GOM.

Risso's dolphin, *Grampus griseus* – Quinault

This species is known from tropical and warm temperate oceans, primarily in waters with surface temperatures between 10 and 28° C (50 and 82˚F) (Reeves et al., 2002). They are mostly found in water depths from 400–1,000 m (1,312–3,281 ft) but are also found on the continental shelf. In the GOM, Risso's are found along the continental slope, particularly areas with steep slope gradient between depths of 375 m (1,230 ft) and 975 m (3,199 ft) (Baumgartner, 1997). Their current distribution is throughout the entire GOM (Maze-Foley and Mullin, 2006); historically sightings have been mostly in spring and near the Mississippi River Delta (Jefferson and Schiro, 1997). The most recent abundance estimate for the northern GOM stock is 2,169 (CV = 0.32)

(Mullin and Fulling, 2004). Density of Risso's dolphins in the eastern GOM is available for two depth regimes: 0.0085/km^2 for 200–2,000 m (656–6,562 ft) and 0.0043/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0027/km^2.

There are no depth distribution data for this species. They are primarily squid eaters and feeding is presumed to take place at night. A study undertaken in the GOM demonstrated that Risso's are distributed non-uniformly with respect to depth and depth gradient (Baumgartner, 1997), utilizing mainly the steep sections of upper continental slope bounded by the 350 m (1,145 ft) and 975 m (3,199 ft) isobaths. Those data agree closely with Blanco et al. (2006), who collected stomach samples from stranded Risso's dolphins in the western Mediterranean. Their results indicated that, based on prey items, Risso's fed on the middle slope at depths ranging from 600-800 m (1,969–2,625 ft). Stomach content analysis from three animals elsewhere in the Mediterranean indicated that Risso's fed on species that showed greater vertical migrations than those ingested by striped dolphins (Ozturk et al., 2007). In lieu of depth distribution information or information on shape of dives, the following are rough estimates of time at depth based on habitat and prey distribution: 50 percent at <50 m (164 ft), 15 percent at 51-200 m (167-656 ft), 15 percent at 201-400 m (659–1,312 ft), 10 percent at 401-600 m (1,316-1,969 ft) and 10 percent at >600 m (1,969 ft).

Rough-toothed dolphin, *Steno bredanensis*

Rough-toothed dolphins are distributed in warm temperate to tropical waters of all oceans. They are the only species to be found in all three depth regimes in the GOM (Waring et al., 2007; Fulling et al., 2003), although they are not one of the more abundant cetaceans in the region. The most recent abundance estimate for the northern GOM stock is 2,233 (Waring et al., 2007). Density of rough-toothed dolphins in the eastern GOM is available from three depth regimes: 0.004/km^2 for 20–200 m (Fulling et al., 2003), 0.0024/km^2 for 200–2000 m, and 0.0014/km^2 for >2000 m (Mullin and Fulling, 2004. Extrapolating this density to the entire OPAREA resulted in a density of 0.0035/km^2.

Rough-toothed dolphins feed on fish and cephalopods, both oceanic and coastal species (Jefferson, 2002b). Based on anatomy, they appear to be adapted to deep diving (Miyazaki and Perrin, 1994), although the maximum record dive is to only 70 m (230 ft) (Jefferson, 2002b). There have been no depth distribution studies done on this species. In lieu of other information, the following is a rough estimation of time at depth: 100 percent at 0–70 m (0–230 ft).

Bottlenose dolphin, *Tursiops truncatus*

Bottlenose dolphins are distributed in all oceans from temperate to tropical latitudes. There are currently four main stocks recognized in the northern GOM (Waring et al., 2007), but two of these stocks are found in water <20 m (66 ft) deep, and are not included in this discussion. Bottlenose dolphins have been sighted throughout the GOM, but sightings are especially prevalent near the 200 m (656 ft) isobath (Maze-Foley and Mullin, 2006) suggesting a potential association with the shelf break (Baumgartner et al., 2001). Bottlenose dolphins are one of only three species that are regularly seen on the continental shelf (<200 m [656 ft]) (Fulling et al., 2003). The abundance of the northern GOM Continental Shelf stock (20–200 m [66-656 ft]), based on surveys conducted from 1998 to 2001, is 25,320 (CV = 0.26) (Fulling et al., 2003). The abundance of the northern GOM Oceanic stock is 2,239 (CV = 0.41) (Mullin and Fulling, 2004). Density of bottlenose dolphins in the eastern GOM is available from two depth regimes: 20–200 m (66-656 ft), 0.109/km^2 and 200–2000 m (656-6,562 ft), 0.0294/km^2 (Fulling et al, 2003; Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0835/km^2.

Bottlenose dolphins feed on a large variety of fish and squid (Wells and Scott, 2002). Several studies on bottlenose dolphin feeding preferences illustrate variation at different geographic locations. Rossbach and Herzing (1997) observed bottlenose dolphins in the Bahamas feeding on the bottom (7-13 m [23-43 ft) by orienting their heads down and moving from side to side, and several species regularly fed on prey along the sea floor (Wells and Scott, 2002). Corkeron and Martin (2004) reported on two dolphins that spent 66 percent of time in top 5 m (16 ft) of water surface; maximum dive depth was greater than 150 m (492 ft) and there was no apparent diurnal pattern. Stomach content analysis from Brazil indicated that small and medium-sized cephalopods were the primary prey of animals found in shelf regions (Santos and Haimovici, 2001), while off Tasmania, bottlenose dolphin prey consisted of oceanic species that were known to commonly occur on the shelf as well (Gales et al. 1992). Klatsky et al. (2007) reported on dive data of dolphins tagged at the Bermuda Pedestal in the north Atlantic. Dolphins dove to at least 492 m (1,614 ft) depth, with deep dives (>100 m [328 ft]) occurring exclusively at night. Dives during the day were to shallower than at night, with 90 percent of all dives to within 50 m (164 ft) of the surface. Based on data presented in Klatsky et al. (2007; Figure 3), the following depth distribution has been estimated for bottlenose dolphins: daytime: 96 percent at <50 m (164 ft), 4 percent at >50 m (164 ft); nighttime: 51 percent at <50 m (164 ft), 8 percent at 50–100 m (164–328 ft), 19 percent at 101-250 m (331-820 ft), 13 percent at 251-450 m (823-1,476 ft) and 9 percent at >450 m (1,476 ft). Data on time spent at the surface were not published; therefore, surface time was included in the least shallow depth category published.

Atlantic spotted dolphin, *Stenella frontalis*

Atlantic spotted dolphins are found only in the tropical and warm temperate waters of the Atlantic (Perrin, 2002e). They inhabit shallow sloping waters, often near the 200 m (656 ft) isobath, and can be found both near shore (>10 m [33 ft] depth) and offshore (up to 500 m [1,640 ft] depth) (Jefferson and Schiro, 1997; Maze-Foley and Mullin, 2006). Atlantic spotted dolphins are one of only three species that are regularly seen on the continental shelf (<200 m) (656 ft) (Fulling et al., 2003). The abundance of the northern GOM Continental Shelf stock (20–200 m [66–656 ft]), based on surveys conducted form 1998-2001, is 30,772 (CV = 0.27) (Fulling et al., 2003). The abundance of the northern GOM Oceanic stock is 175 (CV = 0.84), based on sightings from the western oceanic GOM (Mullin and Fulling, 2004). Density of Atlantic spotted dolphins in the eastern GOM is available from only one depth regime: 20–200 m (66–656 ft), 0.201/km^2 (Fulling et al, 2003). Extrapolating this density to the entire OPAREA resulted in a density of 0.1369/km^2.

Atlantic spotted dolphins feed on epipelagic and meso-pelagic fish, squid, and benthic invertebrates, and there is some evidence for nocturnal feeding (Perrin, 2002e; Richard and

Barbeau, 1994). Stomach contents from animals collected off Brazil yielded small and medium sized cephalopods (Santos and Haimovici, 2001). Davis et al. (1996) attached a satellite-linked time-depth recorder to a single animal in the GOM. Most dives were shallow regardless of the time of day, with the deepest dives to 40–60 m (131–197 ft). Based on this limited information, the depth distribution for Atlantic spotted dolphins is 76 percent at <10 m (33 ft), 20 percent at 10–20 m (33–66 ft) and 4 percent at 21–60 m (69–197 ft).

T. truncatus/S. frontalis combined

Observers on the vessel surveys conducted by Fulling et al. (2003) on the continental shelf waters of the northern GOM were not always able to differentiate between bottlenose dolphins and Atlantic spotted dolphins, particularly at long distances and depending on weather and animal behavior. Therefore, some sightings were recorded as "*T. truncatus + S. frontalis*," and a separate density was calculated for this grouping for the 20–200 m (66–656 ft) depth regime: 0.007/km^2 (Fulling et al., 2003). Extrapolating this density to the entire OPAREA resulted in a density of 0.0048/km^2.

The depth distribution for this combined group will be adopted from that for Atlantic spotted dolphins, as it is more conservative than that for bottlenose dolphins; 76 percent at <10 m (33 ft), 20 percent at 10–20 m (33–66 ft) and 4 percent at 21–60 m (69–197 ft).

Pantropical spotted dolphin, *Stenella attenuata*

Pantropical spotted dolphins are distributed worldwide in tropical and subtropical waters, with distribution extending from 40°N to 40°S (Perrin, 2002a). It is one of the most abundant cetaceans in the GOM, with a widespread distribution (Jefferson and Schiro, 1997; Maze-Foley and Mullin, 2006). The abundance of the northern GOM Continental Shelf stock (20–200 m), based on surveys conducted from 1998 to 2001, is 25,320 (CV = 0.26) (Fulling et al., 2003). The abundance of the northern GOM Oceanic stock is 91,321 (CV = 0.16) (Mullin and Fulling, 2004). Density of pantropical spotted dolphins in the eastern GOM is available from two depth regimes: 0.2482/km^2 for 200–2,000 m (656–6,562 ft) and 0.2983/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0794/km^2.

Pantropical spotted dolphins feed on small epipelagic fish, squid and crustaceans, and may vary their preferred prey seasonally (Perrin, 2002a; Wang et al., 2003). Stomach contents of dolphins collected near Taiwan indicated that the distribution of primary prey was 0–200 m (0–656 ft) at night and >300 m (984 ft) during the day, indicating that these animals feed at night (Wang et al., 2003). One study on this species, conducted in Hawaii, contains dive information (Baird et al., 2001). The biggest differences recorded were in the increase in dive activity at night. During the day, 89 percent of time was spent within 0–10 m (0–33 ft), most of the rest of the time was 10–50 m (33–164 ft), and the deepest dive was to 122 m (400 ft). At night, only 59 percent of time was spent from 0–10 m (0–33 ft) and the deepest dive was to 213 m (699 ft); dives were especially pronounced at dusk. The following depth distributions are applicable: daytime, 89 percent at 0–10 m (0–33 ft) and 11 percent at 11-50 m (36-164 ft), with <1 percent at 51-122 m (167-400 ft); nighttime, 80 percent at 0–10 m (0–33 ft), 8 percent at 11–20 m (36-

66 ft), 2 percent at 21-30 m (69-98 ft), 2 percent at 31-40 m (101-131 ft), 2 percent at 41-50 m (134-164 ft), and 6 percent at 51-213 m (167-699 ft).

Striped dolphin, *Stenella coeruleoalba*

Striped dolphins are distributed in tropical and warm temperate waters of all oceans. They are generally found over the continental slope out to oceanic waters, particularly in areas of upwelling (Archer, 2002). The current abundance estimate for striped dolphins in the northern GOM stock is 6,505 (CV = 0.43), based on surveys conducted from 1996 to 2001 (Mullin and Fulling, 2004). Density of striped dolphins in the eastern GOM is available from two depth regimes: $0.0082/km^2$ for 200–2,000 m (656-6,562 ft) and $0.0147/km^2$ for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of $0.0026/km^2$.

Striped dolphins feed on pelagic fish and squid and may dive during feeding to depths exceeding 200 m (Archer, 2002). However, studies are rare on this species. Stomach content remains from three dolphins in the Mediterranean near Turkey included several species of cephalopod as well as some fish, and suggested that striped dolphins may not feed quite as deep as Risso's dolphins in the same area (Ozturk et al., 2007). Blanco et al. (1995) analyzed stomach content remains from the western Mediterranean, and identified a mixed diet of muscular and gelatinous body squid of pelagic and bathypelagic origin. There is some evidence that striped dolphins feed at night to take advantage of vertical migrations of the deep scattering layer. In lieu of other information, pantropical spotted dolphin depth distribution data will be extrapolated to striped dolphins: daytime, 89 percent at 0–10 m (0–33 ft) and 11 percent at 11-50 m (36-164 ft), with <1 percent at 51-122 m (167-400 ft); nighttime, 80 percent at 0–10 m (0–33 ft), 8 percent at 11-20 m (36-66 ft), 2 percent at 21-30 m (69-99 ft), 2 percent at 31-40 m (102-131 ft), 2 percent at 41-50 m (131-164 ft), and 6 percent at 51-213 m (167-699 ft) (Baird et al., 2001).

Spinner dolphin, *Stenella longirostris*

Spinner dolphins are found in tropical and subtropical waters of all oceans (Perrin, 2002d). In the GOM, they are mostly oceanic, with more sightings in the eastern GOM at >200 m than in the western GOM (Maze-Foley and Mullin, 2006; Jefferson and Schiro, 1997). Abundance of the northern GOM stock is 11,971 (CV = 0.71) (Mullin and Fulling, 2004). Density of spinner dolphins in the eastern GOM is available for two depth regimes: $0.1730/km^2$ for 200–2,000 m (656-6,562 ft) and $0.0042/km^2$ for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of $0.0545/km^2$.

Spinner dolphins feed on small mesopelagic fish, and likely feed at night (Perrin, 2002d; Benoit-Bird and Au, 2003). Stomach content analysis of spinner dolphins collected in the Sulu Sea, Philippines, indicated that they fed on mesopelagic crustaceans, cephalopods and fish that undertake vertical migrations to approximately 250 m (821 ft) (Dolar et al., 2003). There was also evidence that they preyed on non-vertical migrating species found at approximately 400 m (1,312 ft), and that they likely did not have the same foraging range as Fraser's dolphins in the same area (to 600 m [1,969 ft]). Studies on spinner dolphins in Hawaii have been carried out using active acoustics (fish-finders) (Benoit-Bird and Au, 2003). These studies show an extremely close association between spinner dolphins and their prey (small, mesopelagic fish).

Mean depth of spinner dolphins was always within 10 m (33 ft) of the depth of the highest prey density. These studies have been carried out exclusively at night, as stomach content analysis indicates that spinners feed almost exclusively at night when the deep scattering layer moves toward the surface bringing potential prey into relatively shallower (0–400 m [0–1,312 ft]) waters. Prey distribution during the day is estimated at 400–700 m (1,312–2,297 ft). Based on these data, the following are very rough order estimates of time at depth: daytime: 100 percent at 0–50 m (0–164 ft); nighttime: 100 percent at 0–400 m (0–1,312 ft).

Clymene dolphin, *Stenella clymene*

Clymene dolphins are distributed in the tropical and warm temperate waters of the Atlantic Ocean, and are one of the least-known dolphins (Jefferson, 2002c). They are rarely sighted over the continental shelf, with most sightings occurring in deep water (250–5,000 m [821–16,404 ft) (Perrin and Mead, 1994; Fertl et al., 2003). Clymene dolphins appear to be more common in the northwestern GOM than northeastern (Maze-Foley and Mullin, 2006). Abundance of the northern GOM stock is 17,355 (CV = 0.65) (Mullin and Fulling, 2004). Density of clymene dolphins in the eastern GOM is available for only one depth regime: 0.0583/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0002/km^2.

There is little information on the feeding habits of Clymene dolphins, and no diving studies have been carried out. They apparently feed on mesopelagic fish and squid that are vertical migrators, which indicate feeding at night. In lieu of the lack of information specific to this species, the depth distributions for spinner dolphins will be adopted for clymene: Daytime: 100 percent at 0–50 m (0–164 ft); Nighttime: 100 percent at 0–400 m (0–1,312 ft) (Benoit Bird and Au, 2003).

Unidentified *Stenella, Stenella* sp.

Dolphins that could not be identified specifically as striped, spinner, spotted or clymene dolphin were classified as *Stenella* sp by Mullin and Fulling (2004). Density of the *Stenella* group in the eastern GOM was provided for two depth regimes: 0.0012/ km^2 for 200–2,000 m (656–6,652 ft) and 0.0019/km^2 for >2,000 m (6,562 ft) (Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0004/km^2.

The depth distribution for this combined group will be adopted from that for Atlantic spotted dolphins, as it is most conservative for any of the *Stenella* species: 76 percent at <10 m (33 ft), 20 percent at 10–20 m (33-66 ft) and 4 percent at 21-60 m (69-197 ft).

Fraser's dolphin, *Lagenodelphis hosei*

Fraser's dolphins are distributed in tropical waters of all oceans, between 30°N and 30°S (Dolar, 2002). Distribution appears to be oceanic (>200 m [656 ft]) in most areas, and they appear to be more common in the GOM that in adjacent Atlantic waters. Abundance of the northern GOM stock is 726 (CV = 0.70) (Mullin and Fulling, 2004). Density of Fraser's dolphins in the eastern GOM is available for only one depth regime: 0.0112/km^2 for 200–2,000 m (656-6,562 ft)

(Mullin and Fulling, 2004). Extrapolating this density to the entire OPAREA resulted in a density of 0.0035/km^2.

Fraser's dolphins prey on mesopelagic fish, crustaceans and cephalopods, and take advantage of vertically migrating prey at night (Dolar, 2002). Stomach contents from dolphins in the Sulu Sea, Philippines, contained crustaceans, cephalopods and myctophid fish (Dolar et al., 2003). Fraser's dolphins took larger prey than spinner dolphins feeding in the same area, and likely foraged to depths of at least 600 m (1,969 ft), based on prey composition and behavior. This species has also been observed herding fish and feeding at the surface, taking short dives and surfacing in the middle of the herded fish school (Watkins et al., 1994). Based on this very limited information, the following are very rough order estimates of time at depth: daytime, 100 percent at 0–50 m (0–164 ft); nighttime, 100 percent at 0–700 m (0–2,297 ft).

SIRENIANS

West Indian manatee, *Trichechus manatus* – Extralimital

There is no density for the NSWC PCD Study Area.

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
		General Information					**Depth-Specific Information**		
MYSTICETES - Baleen whales									
Bryde's whale	Pelagic schooling fish, small crustaceans (euphausiids, copepods), cephalopods; feeding is regionally different; preferred both anchovy and krill in Northwestern Pacific	Coastal and Offshore; off South Africa inshore form feeds on epipelagic fish (e.g., anchovies) while offshore form feeds on mesopelagic fish and euphausiids	Kato (2002); Murase et al. (2007); Best (1977); Bannister (2002)	Feeding	South Pacific and Indian Oceans	Main prey items were euphausiids, including *Euphausia* sp and *Thysanoessa* sp; most feeding apparently at dawn and dusk		Several hundred/ year-round/ stomach content	Kawamura (1980)
ODONTOCETES - Toothed whales									
Sperm whale	Squid and other cephalopods, demersal and mesopelagic fish; varies according to region	Deep waters, areas of upwelling	Whitehead (2002); Roberts (2003)	Feeding	Mediterranean Sea	Overall dive cycle duration mean = 54.78 min, with 9.14 min (17 percent of time) at the surface between dives; no		16 whales/ July-August/ visual observations and click recordings	Drouot et al. (2004)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						measurement of depth of dive			
Sperm whale				Feeding	South Pacific (Kaikoura, New Zealand)	83 percent of time spent underwater; no change in abundance between summer and winter but prey likely changed between seasons		>100 whales/ Year-round/ visual observations	Jacquet et al. (2000)
Sperm whale				Feeding	Equatorial Pacific (Galapagos)	Fecal sampling indicated four species of cephalopods predominated diet, but is likely biased against very small and very large cephalopods; samples showed variation over time and place		Several whales/ January-June/ fecal sampling	Smith and Whitehead (2000)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
Sperm whale				Feeding	Equatorial Pacific (Galapagos)	Dives were not to ocean floor (2000-4000 m) but were to mean 382 m in one year and mean of 314 in another year; no diurnal patterns noted; general pattern was 10 min at surface followed by dive of 40 min; clicks (indicating feeding) started usually after descent to few hundred meters		Several whales/ January-June/ acoustic sampling	Papastavrou et al. (1989)
Sperm whale				Feeding	North Pacific (Baja California)	Deep dives (>100m) accounted for 26 percent of all dives; average depth 418 +-216 m; most	74 percent in <100 m; 24 percent in 100-500 m; 2 percent in >500m	Five whales/ October-November/ Satellite-linked dive recorder	Davis et al. (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						(91 percent) deep dives were to 100-500 m; deepest dives were 1250-1500m; average dive duration was 27 min; average surface time was 8.0; whale dives closely correlated with depth of squid (200-400 m) during day; nighttime squid were shallower but whales still dove to same depths			
Sperm whale				Resting/ socializing	North Pacific (Baja California)	Most dives (74 percent) shallow (8-100 m) and short duration; likely resting and/or socializing		Five whales/ October-November/ Satellite-linked dive recorder	Davis et al. (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
Sperm whale				Feeding	North Atlantic (Norway)	Maximum dive depths near sea floor and beyond scattering layer		Unknown # male whales/ July/ hydrophone array	Wahlberg (2002)
Sperm whale				Feeding	North Pacific (Southeast Alaska)	Maximum dive depth if 340 m when fishing activity was absent; max dive depth during fishing activity was 105 m		Two whales/ May/ acoustic monitoring	Tiemann et al. (2006)
Sperm whale				Feeding	Northwest Atlantic (Georges Bank)	Dives somewhat more U-shaped than observed elsewhere; animals made both shallow and deep dives; average of 27 percent of time at surface; deepest dive of 1186 m while		Nine Whales/ July 2003/ DTAG	Palka and Johnson (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						deepest depths in area were 1500-3000 m so foraging was mid-water column; surface interval averaged 7.1 min			
Sperm whale				Feeding	Northwest Atlantic (Georges Bank)	37 percent of total time was spent near surface (0-10m); foraging dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	48 percent in <10 m; 3 percent in 10-100 m; 7 percent in 101-300 m; 7 percent in 301-500 m; 4 percent in 501-636 m; 31 percent in >636 m	Six females or immatures/ September-October/ DTAG	Watwood et al. (2006)
Sperm whale				Feeding	Mediterranean Sea	20 percent of total time was spent near surface (0-10 m); foraging	35 percent in <10 m; 4 percent in 10-100 m; 9 percent in 101-300 m;	Eleven females or immatures/ July/ DTAG	Watwood et al. (2006)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	9 percent in 301-500 m; 5 percent in 501-623 m; 38 percent in >636 m		
Sperm whale				Feeding	GOM	28 percent of total time was spent near surface (0-10m); foraging dive statistics used to calculate percentages of time in depth categories, adjusted for total time at surface	41 percent in <10 m; 4 percent in 10-100 m; 8 percent in 101-300 m; 7 percent in 301-468 m; 40 percent >468 m	20 females or immatures/ June-September/ DTAG	Watwood et al. (2006)
Sperm whale				Feeding/ Resting	North Pacific (Japan)	Dives to 400-1200 m; active bursts in velocity at bottom of dive suggesting	**31 percent in <10 m (surface time); 8 percent in 10-200 m; 9 percent in**	One female/ June/ Time-depth-recorder	Amano and Yoshioka (2003)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						search-and-pursue strategy for feeding; 14 percent of total time was spent at surface not feeding or diving at all, with 86 percent of time spent actively feeding; used numbers to determine percentages of time in each depth category during feeding then adjusted by total time at surface	**201-400 m; 9 percent in 401-600 m; 9 percent in 601-800m; 34 percent in >800 m**		
Sperm whale				Feeding/ Resting	North Atlantic (Caribbean)	Whales within 5 km of shore during day but moved offshore at night; calves remained mostly at		Two whales/ October/ Acoustic transponder	Watkins et al. (1993)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						surface with one or more adults; night time tracking more difficult due to increased biological noise from scattering layer; both whales spent long periods of time (>2hr) at surface during diving periods			
Sperm whale					North Atlantic (Caribbean)	Dives did not approach bottom of ocean (usually >200 m shallower than bottom depth); day dives deeper than night dives but not significantly; 63 percent of total time in deep		One whale/ April/ Time-depth tag	Watkins et al. (2002)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						dives with 37 percent of time near surface or shallow dives (within 100 m of surface)			
Pygmy sperm whale	Mid and deep water cephalopods, fish, crustaceans; probably feeding at or near bottom, possibly using suction feeding	Continental slope and deep zones of shelf, epi- and meso-pelagic zones	McAlpine (2002); McAlpine et al. (1997)	Feeding	Northwest Atlantic (Canada)	Prey items included squid beaks, fish otolith and crustacean; squid representative of mesopelagic slope-water community		One whale/ December/ Stomach contents	McAlpine et al. (1997)
Pygmy sperm whale				Feeding	Southwest Atlantic (Brazil)	Small to medium-sized cephalopods from offshore regions Cephalopods and fish found in animals from shelf regions		Unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Pygmy sperm whale				Feeding	South Pacific	Primarily cephalopod		27 whales/ Year round/	Beatson (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
					(New Zealand)	prey of genus *Histioteuthis* sp, mostly immatures, which is know to undergo vertical migrations; also mysides that are usually found at 650 m during day and between 274 and 650 m at night; some prey species also found in shallower (<100 m) depths in trawls		Stomach contents	
Dwarf sperm whale	Likely feeds in shallower water than *K breviceps*; otherwise food is similar	Continental slope and deep zones of shelf, epi- and meso-pelagic zones	McAlpine (2002)						
Cuvier's beaked whale	Meso-pelagic or deep water	Offshore, deep waters	Heyning (2002);	Feeding	Northeast Pacific	Max dive depth =		Two whales/ September-	Baird et al. (2006a);

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
	benthic organisms, particularly squid (Cephalapoda: Teuthoidea); may have larger range of prey species than other deep divers; likely suction feeders based on lack of teeth and enlarged hyoid bone and tongue muscles	of continental slope (200-2000 m) or deeper	Santos et al. (2001); Blanco and Raga (2000)		(Hawaii)	1450 m; identified at least three dive categories including inter-ventilation (<4 m, parabolic shape), long duration (>1000m, U-shaped but with inflections in bottom depth), and intermediate duration (292-568 m, U-shaped); dive cycle usually included one long duration per 2 hours; one dive interval at surface of >65 min; mean depth at tagging was 2131 m so feeding occurred at		November/ Time-depth recorders	Baird et al. (2005a)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						mid-depths; no difference between day and night diving			
Cuvier's beaked whale				Feeding	Mediterranean (Ligurian Sea)	Two types of dive, U-shaped deep foraging dives (>500 m, mean 1070 m) and shallower non-foraging dives (<500 m, mean 221 m).	**27 percent in <2 m (surface); 29 percent in 2-220 m; 4 percent in 221-400 m; 4 percent in 401-600 m; 4 percent in 601-800 m; 5 percent in 801-1070; 27 percent in >1070 m**	Seven whales/ June/ DTAGs	Tyack et al. (2006)
Cuvier's beaked whale				Feeding	Mediterranean (Ligurian Sea)	Deep dives broken into three phases: silent descent, vocal-foraging and silent ascent; vocalizations not detected <200m depth; detected		Two whales/ September/ DTAGs	Johnson et al. (2004); Soto et al. (2006)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						when whales were as deep as 1267 m; vocalizations ceased when whale started ascending from dive; clicks ultrasonic with no significant energy below 20 kHz			
Blainville's beaked whale	Feed primarily on mesopelagic squid (Histioteuthis, Gonatus) and some mesopelagic fish; most prey probably caught at >200 m; likely suction feeders based on lack of teeth and enlarged hyoid bone and tongue muscles		Pitman (2002b)	Feeding	Northeast Pacific (Hawaii)	Max dive depth = 1408 m; identified at least three dive categories including inter-ventilation (<5 m), long duration (>800m, U-shaped but with inflections in bottom depth), and intermediate duration		Four whales/ September-November/ Time-depth recorders	Baird et al. (2006a); Baird et al. (2005a)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						(6-300 m, U-shaped); dive cycle usually included one long duration,~8 intermediate duration and several shallow interventilation dives; one surface interval of >154 min; no difference between day and night diving			
Blainville's beaked whale				Feeding	Northeast Pacific (Hawaii)	Mean max dive depth = 1365 m; whales appeared to coordinate dives to ~600 m after which coordination of depths was not prevalent; dives >800 m (>65 min)		Three whales/ March-April/ Time-depth recorders	Baird et al. (2006b)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						occurred once/2.5 hour; likely feeding in mid-depth, not bottom feeding			
Blainville's beaked whale				Feeding	Northeast Atlantic (Canary Islands)	Two types of dive, U-shaped deep foraging dives (>500 m, mean 835m) and shallower non-foraging dives (<500 m, mean 71 m).	**26 percent in <2 m (surface); 41 percent in 2-71 m; 2 percent in 72-200 m; 4 percent in 201-400 m; 4 percent in 401-600 m; 4 percent in 601-835; 19 percent in >835 m**	Three whales/ June/ DTAGs	Tyack et al. (2006)
Blainville's beaked whale				Feeding	Northeast Atlantic (Canary Islands)	Deep dives broken into three phases: silent descent, vocal-foraging (including search, approach and terminal phases) and silent ascent;		Two whales/ September/ DTAGs	Johnson et al. (2004); Madsen et al. (2005)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						vocalizations not detected <200m depth; detected when whales were as deep as 1267 m; vocalizations ceased when whale started ascending from dive; clicks ultrasonic with no significant energy below 20 kHz			
Sowerby's beaked whale	Likely meso-pelagic or deep water benthic organisms; likely suction feeders based on lack of teeth and enlarged hyoid bone and tongue muscles	Offshore, deep waters of continental slope (200-2000 m) or deeper	Pitman (2002b)						

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
Gervais' beaked whale	Likely meso-pelagic or deep water benthic cephalopods; likely suction feeders based on lack of teeth and enlarged hyoid bone and tongue muscles	Offshore, deep waters of continental slope (200-2000 m) or deeper	Pitman (2002b)						
Killer whale	Diet includes fish (salmon, herring, cod, tuna) and cephalopods, as well as other marine mammals (pinnipeds, dolphins, mustelids, whales) and sea birds; most populations show marked dietary specializatio n	Widely distributed but more commonly seen in coastal temperate waters of high productivity	Ford (2002); Estes et al. (1998); Ford et al. (1998); Saulitis et al. (2000); Baird et al. (2006c)	Feeding	North Pacific (Puget Sound)	Resident-type (fish-eater) whales; maximum dive depth recorded 264 m with maximum depth in Study Area of 330 m; population appeared to use primarily near-surface waters most likely because prey was available there; some	**96 percent at 0-30 m; 4 percent at >30 m**	Eight whales/ Summer-fall/ Time-depth recorders	Baird et al. (2005b); Baird et al. (2003a)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						difference between day and night patterns and between males and females depth distribution info from Table 5 in Baird et al. (2003)			
Killer whale				Feeding	Southwest Atlantic (Brazil)	Small to medium-sized cephalopods, both offshore and coastal		Unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
False killer whale	Oceanic squid and fish, but also smaller marine mammals	Mainly pelagic but close to shore near oceanic islands	Baird (2002a); Koen Alonso et al. (1999); Santos and Haimovici (2001)		North Pacific (Hawaii)	Most dives relatively shallow (<53 m) and dive duration was not a predictor of dive depth		Three whales/ Time-depth recorders	Ligon and Baird (2001)
False killer whale				Feeding	Southwest Atlantic (Brazil)	Medium-sized cephalopods in slope regions		Three animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Pygmy killer	Cephalopods	Mainly	Donahue	Feeding	Southwest	Found in		1 animal/	Santos and

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
whale	and small fish, but also likely small delphinids	pelagic but close to shore near oceanic islands	and Perryman (2002)		Atlantic (Brazil)	slope-oceanic areas; fed on cephalopods and fish		unknown/ stomach contents	Haimovici (2001)
Risso's dolphin	Primarily squid eaters and presumably eat mainly at night	Water depths from 400-1000 m but also on continental shelf; utilize steep sections of continental slope in GOM (350-975 m)	Baird (2002b); Baumgartner (1997)	Feeding	Mediterranean (western)	Prey items were mainly squid and octopods, and indicated that most feeding occurs on the middle slope from 600-800 m		15 animals/ year round/ stomach contents	Blanco et al. (2006)
Risso's dolphin	Primarily squid eaters and presumably eat mainly at night			Feeding	Mediterranean (Turkey)	Prey species (pelagic cephalopods) show greater degree of vertical distribution compared to those utilized by *S. coeruleoalba*; may indicate they dive deeper or are more likely to feed at night		Two animals/ May-June/ stomach contents	Ozturk et al. (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
Bottlenose dolphin	Large variety of fish and squid, variable between regions; surface, pelagic and bottom fish have all been taken	Coastal, but can also be found on the continental slope, shelf and shelf break	Wells and Scott (2002); Shane et al. (1986)	Feeding	Southwest Atlantic (Brazil)	Small and medium-sized cephalopods found in animals from shelf regions		unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Bottlenose dolphin				Feeding	Southern Ocean (Tasmania)	Prey items included oceanic species that commonly come onto the continental shelf; fairly large-bodied species compared to other regions		Three animals/ July-October/ stomach contents	Gales et al. (1992)
Bottlenose dolphin				Feeding	Tropical Atlantic (Bahamas)	Fed at depths of 7-13 m along the sandy bottom; prey included benthic fish and eels		May-September/ behavioral observations	Rossbach and Herzing (1997)
Bottlenose dolphin				Feeding	Tropical Atlantic (Bahamas)	Daytime dives tended to be	**Daytime: 96 percent at <50 m,**	3 animals/ June 2003/ satellite-	Klatsky et al. (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						shallow (96 percent within 50 m of surface); diel dive cycle; deeper and more frequent night time dives correlated with nightly vertical migration of mesopelagic prey; depth distribution taken from info in Figure 3; data on time spent at the surface were not published, therefore it was included in the least shallow depth category published	**4 percent at >50 m; Nighttime: 51 percent at <50 m, 8 percent at 50-100 m, 19 percent at 101-250 m, 13 percent at 251-450 m and 9 percent at >450 m**	linked time-depth recorders	
Bottlenose dolphin				Feeding	South Pacific (Australia)	66 percent of time in top		2 animals/ April-November/	Corkeron and Martin (2004)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						5 m of water surface; maximum dive depth >150 m; no apparent diurnal pattern; no relationship between duration and maximum depth of dives		satellite-linked time-depth recorders	
Rough-toothed dolphin	fish and cephalopods, both coastal and oceanic		Jefferson (2002b); Miyazaki and Perrin (1994)			Max recorded dive to 70 m	**100 percent at 0-70 m**	Unknown	Jefferson (2002b)
Rough-toothed dolphin				Feeding	Southwest Atlantic (Brazil)	Small and medium-sized cephalopods found in animals from shelf regions		Unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Pantropical spotted dolphin	Small epipelagic fish, squid and crustaceans for offshore forms; nearshore	Near shore and offshore, with possible shifts closer to shore in fall and winter; in eastern	Perrin (2002a); Richard and Barbeau (1994); Robertson and Chivers	Feeding	Southwest Pacific (Taiwan)	Feed primarily on mesopelagic prey, particularly myctophid lanternfish and		45 animals/ year round/ stomach contents	Wang et al. (2003)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
	forms may feed on benthic fish; perhaps some nocturnal feeding; probably opportunistic	tropical Pacific often found in association with tuna; diet suggest feeding at night on vertically migrating prey	(1987)			cephalopods, with some seasonal differences; night distribution of prey appears to be 0-200 m while daytime distribution of prey is >300 m			
Pantropical spotted dolphin				Feeding	North Pacific (Hawaii)	Dives deeper at night (mean = 57 m, max = 213 m) than during day (mean = 13 m, max = 122 m) indicating night diving takes advantage of vertically migrating prey; during daytime, 89 percent of time was within 0-10 m; depth	**Daytime, 89 percent at 0-10 m, 10 percent at 11-50 m, 1 percent at 51-122 m; Nighttime, 80 percent at 0-10 m, 8 percent at 11-20 m, 2 percent at 21-30 m, 2 percent at 31-40 m, 2 percent at 41-50 m, and 6 percent at 51-213 m.**	Six animals/ year round/ time-depth recorders	Baird et al. (2001)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						distribution taken from info in figure 4			
Atlantic spotted dolphin	Epipelagic and meso-pelagic fish, squid and benthic invertebrates; perhaps some nocturnal feeding	Shallow sloping waters of continental shelf, often near 200 m curve; may be found nearer to shore	Perrin (2002e); Richard and Barbeau (1994)	Feeding	Southwest Atlantic (Brazil)	Small and medium-sized cephalopods found in animals from shelf regions		Unknown animals/ unknown/ stomach contents	Santos and Haimovici (2001)
Atlantic spotted dolphin				Feeding	GOM	Most dives shallow regardless of time of day; 58 percent of dives were 4-10 m; 94 percent were less than 30 m; deepest dives to 40-60 m; depth distribution taken from info in Figure 3	**76 percent in <10 m; 20 percent in 10-20 m; 4 percent in 21-60 m**	One animal/ March-April/ satellite-linked time-depth recorder	Davis et al. (1996)
Striped dolphin	Feed on pelagic fish	Continental slope,	Archer (2002);	Feeding	Mediterranean (Turkey)	Prey species (pelagic		Three animals/	Ozturk et al. (2007)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
	and squid; squid make up 50-100 percent of stomach contents in Mediterranean samples	convergence zones and areas of upwelling; ranges of known prey and presence of luminescent organs in prey indicate feeding at night, possibly 200-700 m	Archer and Perrin (1999)			cephalopods) show lesser degree of vertical distribution compared to those utilized by *G. griseus*		May-June/ stomach contents	
Striped dolphin				Feeding	Mediterranean (western)	Mixed diet of muscular and gelatinous body squid, mainly consisting of oceanic and pelagic or bathypelagic species		28 animals/ unknown/ stomach contents	Blanco et al. (1995)
Striped dolphin				Feeding	North Pacific (Japan)	Myctophid fish accounted for 63 percent of prey		unknown animals/ unknown/ stomach contents	Archer and Perrin (1999)
Spinner dolphin	Small mesopelagic fish, although	Pantropical; often high-seas, but	Perrin (2002d); Benoit-Bird	Feeding	Southwest Pacific (Sulu Sea,	Mainly feed on mesopelagic		45 animals/ unknown/ stomach	Dolar et al. (2003)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
	sub-populations consume benthic fish	coastal populations are also known; dives to 600 m or deeper	and Au (2003)		Philippines)	crustaceans, cephalopods and fish that undertake vertical migrations to about 200 m at night, with less reliance on non-migrating species found to about 400 m; take smaller prey than Fraser's feeding in same area		contents	
Spinner dolphin				Feeding	North Pacific (Hawaii)	Extremely close association with small, mesopelagic fish; mean depth always within 10 m of the depth of the highest prey density; feeding at night occurs between 0-400 m as	**Daytime 100 percent at 0-50 m; Nighttime: 100 percent at 0-400 m**	Several animals/ June and November/ active acoustic surveys	Benoit-Bird and Au (2003)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						that is the nighttime prey distribution (prey distribution during the day is estimated at 400-700 m); did not spend entire night offshore but often within 1 km of shore if prey density was highest there			
Clymene dolphin	Mesopelagic fish and squid including some that are vertical migrators; also observed feeding near surface	Observed only in deep water (250-5000 m depth); rarely sighted over continental shelf	Jefferson (2002c); Perrin and Mead (1994); Fertl et al. (2003)						
Fraser's dolphin	Mesopelagic fish, crustaceans and cephalopods;	Tropical and oceanic except in places where deep water is	Dolar (2002); Dolar et al. (2003); Jefferson	Feeding	Caribbean (Dominica)	Herding and feeding of fish school at surface during		60-80 animals/ October/ behavioral observations	Watkins et al. (1994)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
	take advantage of vertically migrating prey at night	close to islands; likely feed to at least 500 m and possibly at night	and Leatherwood (1994)			daylight hours; depth at location varied from 150-200 m to 2000-2500 m; short dives as animals sometimes approached the herded fish from below			
Fraser's dolphin				Feeding	Southwest Pacific (Sulu Sea, Philippines)	Mesopelagic crustaceans, cephalopods and fish; take larger prey than spinners feeding in same area; likely forage to 600 m but also taking advantage of vertical migrants to 200 m	**Daytime, 100 percent at 0-50 m; Nighttime, 100 percent at 0-700 m**	37 animals/ unknown/ stomach contents	Dolar et al. (2003)
Fraser's dolphin				Feeding	Southwest Atlantic (Brazil)	Cephalopods and fish found in animals from shelf-		4 animals/ unknown/ stomach contents	Santos and Haimovici (2001)

Table A-11. Summary of Depth Information for Marine Mammal Species with Densities in the NSWC PCD Study Area Cont'd

Common Name	Food Preference	Depth or Oceanic Preference	References	Behavioral State	Geographic Region	Depth Information	Depth Distribution	Sample Size/Time of Year/ Method	References
						slope regions			

A.6 REFERENCES

Aguilar, A., 2002. Fin whale. Pp. 435-438 In: W. F. Perrin, B. Wursig and J.G.M. Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Amano, M and M.,Yoshioka 2003. Sperm whale diving behavior monitored using a suction-cup-attached TDR tag. *Marine Ecology Progress Series* 258: 291-295.

Archer II, F. I., 2002. Striped dolphin. Pp. 1201-1203 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Archer, II, F. I. and W. F.Perrin , 1999. *Stenella coeruleoalba. Mammalian Species* 603:1-9.

Baird, R. W., 2002a. False killer whale. Pp 411-412 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Baird, R. W., 2002b. Risso's dolphin. Pp. 1037-1039 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Baird, R. W., D. L.Webster, D. J. McSweeney, A. D. Ligon, G. S.Schorr, and J.Barlow, 2006a. Diving behaviour of Cuvier's (*Ziphius cavirostris*) and Blainville's (*Mesoplodon densirostris*) beaked whales in Hawaii. *Canadian Journal of Zoology* 84: 1120-1128.

Baird, R. W., G. S. Schorr, D. L. Webster, D. J. McSweeney, and S. D. Mahaffy, 2006b. Studies of beaked whale diving behavior and odontocete stock structure in Hawaii in March/April 2006. Report prepared under Contract No AB133F-06-CN-0053 to Cascadia Research Collective, Olympia, WA from the Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, CA. Available from www.cascadiaresearch.org.

Baird, R. W., D. J. McSweeney, C. Bane, J. Barlow, D. R. Salden, L. K. Antoine, R. LeDuc and D. L. Webster, 2006c. Killer whales in Hawaiian waters: information on population identity and feeding habits. *Pacific Science* 60: 523-530.

Baird, R. W., D. L. Webster, D. J. McSweeney, A. D. Ligon, and G. S. Schorr, 2005a. Diving Behavior and ecology of Cuvier's (*Ziphius cavirostris*) and Blainville's beaked whales (*Mesoplodon densirostris*) in Hawaii. Report prepared by Cascadia Research Collective for the Southwest Fisheries Science Center. Available from www.cascadiaresearch.org.

Baird, R. W., M. B. Hanson and L. M. Dill, 2005b. Factors influencing the diving behaviour of fish-eating killer whale: Sex differences and diel and interannual variation in diving rates. *Canadian Journal of Zoology* 83(2):257-267.

Baird, R. W., M. B. Hanson, E. E. Ashe, M. R. Heithaus and G. J. Marshall, 2003a. Studies of foraging in "southern resident" killer whales during July 2002: dive depths, bursts in speed, and the use of a "crittercam" system for examining sub-surface behavior. Report prepared under Order number AB133F-02-SE-1744 for NMFS-NMML. Available from www.cascadiaresearch.org.

Baird, R. W., A. D. Ligon, S. K. Hooker and A. M. Gorgone, 2001. Subsurface and nighttime behavior of pantropical spotted dolphins in Hawaii. *Canadian Journal of Zoology* 79: 988-996.

Bannister, J. L., 2002. Baleen whales. Pp. 62-72 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Baumgartner, M. F., 1997. The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. *Marine Mammal Science* 13(3): 614-638.

Baumgartner, M. F, KD Mullin, LN May and TD Leming, 2001. Cetacean habitats in the northern Gulf of Mexico. *Fishery Bulletin* 99: 219-239

Beatson, E., 2007. The diet of pygmy sperm whales, *Kogia breviceps*, stranded in New Zealand: implications for conservation. *Rev Fish Biol Fisheries* 17:295–303.

Benoit-Bird, K. J and W. W. L. Au, 2003. Prey dynamics affect foraging by a pelagic predator (*Stenella longirotris*) over a range of spatial and temporal scales. *Behavioral Ecology and Sociobiology* 53: 364-373.

Best, P. B., 1977. Two allopatric forms of Bryde's whale off South Africa. *Rep. Int. Whal. Commn* (Spec Iss 1): 10-38.

Blanco C. and J. A. Raga, 2000. Cephalopod prey of two *Ziphius cavirostris* (Cetacea) stranded on the western Mediterranean coast. *Journal of the Marine Biological Association of the United Kingdom* 80 (2): 381-382

Blanco, C, M. A. Raduan and J. A. Raga, 2006. Diet of Risso's dolphin (*Grampus griseus*) in the western Mediterranean Sea. *Scientia Marina* 70(3): 407-411.

Blanco, C., J. Aznar and J. A. Raga, 1995. Cephalopods in the diet of the striped dolphin *Stenella coeruleoalba* from the western Mediterranean during an epizootic in 1990. *Journal of Zoology* 237 (1): 151-158.

Blix, A. S. and L. P. Folkow, 1995. Daily energy expenditure in free living minke whales. *Acta Physiologica Scandinavica* 153(1): 61-6.

Bonde, R. K. and T. J. O-Shea, 1989. Sowerby's beaked whale (*Mesoplodon bidens*) in the Gulf of Mexico. *Journal of Mammalogy* 70(2): 447-449.

Clapham, P. J., 2002. Humpback whale. Pp. 589-592 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Corkeron P. J. and A. R. Martin, 2004. Ranging and diving behaviour of two 'offshore' bottlenose dolphins, *Tursiops* sp., off eastern Australia. *Journal of the Marine Biological Association of the United Kingdom* 84:465-468

Davis, R. W., N. Jaquet, D. Gendron, U. Markaida, G. Bazzino and W. Gilly, 2007. Diving behavior of sperm whales in relation to behavior of a major prey species, the jumbo squid, in the Gulf of California, Mexico. *Marine Progress Series* 333: 291-302.

Davis, R. W., G. A. J. Worthy, B. Wursig and S. K. Lynn, 1996. Diving behavior and at-sea movements of an Atlantic spotted dolphin the Gulf of Mexico. *Marine Mammal Science* 12(4): 569-581.

Department of the Navy, 2007. Marine resource assessment for the Gulf of Mexico. Department of the Navy, US Fleet Forces Command, Norfolk, VA. Contract #N62470-02-D-9997, CTO 0030. Prepared by Geo-Marine, Inc., Hampton, VA. Available from https://portal.navfac.navy.mil/portal/page?_pageid=181,3986942&_dad=portal&_schema=PORTAL.

Dolar, M. L. L., 2002. Fraser's dolphin. Pp. 485-487 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Dolar, M. L. L., W.A. Walker, G.L. Kooyman and W.F. Perrin, 2003. Comparative feeding ecology of spinner dolphins (*Stenella longirostris*) and Fraser's dolphins (*Lagenodelphis hosei*) in the Sulu Sea. *Marine Mammal Science* 19(1): 1-19.

Donahue, M. A. and W. A. Perryman, 2002. Pygmy killer whale. Pp. 1009-1010 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Drouot, V., A. Gannier, and J. C. Goold, 2004. Diving and feeding behaviour of sperm whales (*Physeter macrocephalus*) in the northwestern Mediterranean Sea. *Aquatic Mammals* 30(3): 419-426.

Estes, J. A., M. T. Tinker, T. M. Williams and D. F. Doak, 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. *Science* 282: 473-476.

Fertl, D., T. A. Jefferson, I. B. Moreno, A. N. Zerbini and K. D. Mullin, 2003. Distribution of the Clymene dolphin *Stenella clymene*. *Mammal Review* 33(3): 253-271.

Ford, J. K. B., 2002. Killer whale. Pp. 669-676 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Ford, J. K. B., G. M. Ellis, L. G. Barrett-Lennard, A. B. Morton, R. S. Palm and K. C. Balcomb III, 1998. Dietary specialization in two sympatric populations of killer whale (*Orcinus orca*) in coastal British Columbia and adjacent waters. *Canadian Journal of Zoology* 76: 1456-1471.

Fulling, G. L., K. D. Mullin and C. W. Hubbard, 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the US Gulf of Mexico. *Fishery Bulletin* 101: 923-932.

Gales, R., D. Pemberton, M. Clarke and C. C. Lu, 1992. Stomach contents of long-finned pilot whales (*Globicephala melaena*) and bottlenose dolphins (*Tursiops truncatus*) in Tasmania. *Marine Mammal Science* 8 (4): 405–413.

Garrison, L., 2007. Personal communication, 9/11/07. National Marine Fisheries Center, Southwest Fisheries Science Center.

Heyning, J. E., 2002. Cuvier's beaked whale. Pp 305-307 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Horwood, J., 2002. Sei whale. Pp. 1069-1071 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Jaquet, N., S. Dawson and E. Slooten, 2000. Seasonal distribution and diving behavior of male sperm whales off Kaikoura: foraging implications. *Canadian Journal of Zoology* 78(3): 407-419.

Jefferson, T. A. and A. J. Schiro, 1997. Distribution of cetaceans in the offshore Gulf of Mexico. *Mammal. Review* 27(1): 27-50.

Jefferson, T. A. and S. Leatherwood, 1994. *Lagenodelphis hosei*. *Mammalian Species* 470:1-5.

Jefferson, T. A., S. Leatherwood and M. A. Webber, 1993. Marine mammals of the world. *FAO Species Identification Guide.* United Nations Environment Programme, Food and Agriculture Organization of the United Nations. 320 pp.

Jefferson, T. A., 2002b. Rough-toothed dolphin. Pp. 1055-1059 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Jefferson, T. A., 2002c. Clymene dolphin. Pp. 234-236 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Jochens, A. E. and D. C. Biggs, eds., 2006. Sperm whale seismic study in the Gulf of Mexico; Annual Report: Years 3 and 4. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2006-067. 111 pp. Available from http://www.gomr.mms.gov.

Johnson, M., P. T. Madsen, W. M. X. Zimmer, N. Aguilar de Soto, and P. L. Tyack, 2004. Beaked whales echolocate on prey. *Proceedings of the Royal Society, London B* (Suppl.) 271: S383-S386.

Kato, H., 2002. Bryde's whales. Pp 171-177 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Kawamura, A., 1980. Food habits of the Bryde's whales taken in the South Pacific and Indian Oceans. *Sci. Rep. Whales Res. Inst*. 32: 1-23.

Klatsky, L. J., R. S. Wells and J. C. Sweeney, 2007. Offshore bottlenose dolphins (*Tursiops truncatus*): Movement and dive behavior near the Bermuda Pedestal. *Journal of Mammalogy* 88(1):59-66.

Koen Alonso, M., S. N. Pedraza, A. C. M. Schiavini, R. N. P. Goodall and E. A. Crespo, 1999. Stomach contents of false killer whales (*Pseudorca crassidens*) stranded on the coasts of the Strait of Magellan, Tierra del Fuego. *Marine Mammal Science* 15(3): 712-724.

Ligon, A. D. and R. W. Baird, 2001. Diving behavior of false killer whales off Maui and Lana'i, Hawaii. Abstract presented at 14th Biennial Conference on the Biology of Marine Mammals, Vancouver, Canada, December, 2001. Available from www.cascadiaresearch.org.

London, J. M., 2006. Harbor seals in Hood Canal: Predators and Prey. PhD Dissertation, University of Washington.

Madsen, P. T., M. Johns, N. Aguilar de Soto, W. M. X. Zimmer and P. Tyack, 2005. Biosonar performance of foraging beaked whales (*Mesoplodon densirostris*). *The Journal of Experimental Biology* 208: 181-194.

McAlpine, D. F., 2002. Pygmy and dwarf sperm whales. Pp. 1007-1009 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

McAlpine, D. F., L. D. Murison and E. P. Hoberg, 1997. New records for the pygmy sperm whale, *Kogia breviceps* (Physeteridae) from Atlantic Canada with notes on diet and parasites. *Marine Mammal Science* 13(4): 701-704.

Miyazaki N. and W. F. Perrin, 1994. Rough-toothed dolphin *Steno bredanensis* (Lesson, 1828). Pp 1-22 In: SH Ridgway and SR Harrison (eds.), *Handbook of Marine Mammals* Vol. 5: The first book of dolphins. Academic Press, London.

Mullin, K. A., 2007. Personal communication, 9/9/07. National Marine Fisheries Center, Southwest Fisheries Science Center.

Mullin, K. D. and G. L. Fulling, 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. *Marine Mammal Science* 20(4): 787-807.

Mullin, K. D., W. Hoggard and L. J. Hansen, 2004. Abundance and seasonal occurrence of cetaceans in Outer Continental Shelf and Slope waters of the north-central and northwestern Gulf of Mexico. *Gulf of Mexico Science* 22(1): 62-73.

Murase, H., T.Tamura, H. Kiwada, Y. Fujise, H. Watanabe, H. Ohizumi, S. Yonezaki, H. Okamura and S . Kawahura, 2007. Prey selection of common minke (*Balaenoptera acutorostrata*) and Bryde's (*Balaenoptera edeni*) whales in the western North Pacific in 2000 and 2001. *Fisheries Oceanography* 16(2): 186-201.

Olson, P. A. and S. B. Reilly, 2002. Pilot whales. Pp. 898-903 In: W. F. Perrin, B. Wursig and J. G. M. Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Ozturk, B., A. Salman, A. A. Ozturk and A. Tonay, 2007. Cephalopod remains in the diet of striped dolphins (*Stenella coeruleoalba*) and Risso's dolphins (*Grampus griseus*) in the eastern Mediterranean Sea. *Vie et Milieu - Life and Environment* 57(1/2): 53-59

Palka, D. and M. Johnson, eds., 2007. Cooperative research to study dive patterns of sperm whales in the Atlantic Ocean. OCS Study MMS 2007-033. New Orleans, Louisiana: Gulf of Mexico Region, Minerals Management Service. Available from http://www.gomr.mms.gov.

Papastavrou V, S. C. Smith and H. Whitehead, 1989. Diving behavior of the sperm whale, *Physeter macrocephalus*, off the Galapagos Islands [Ecuador]. *Canadian Journal of Zoology* 67:839-846

Perrin, W. F., 2002a. Pantropical spotted dolphin. Pp. 865-867 In: W. F. Perrin, B. Wursig and J. G. M. Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, W. F., 2002d. Spinner dolphin. Pp. 1174-1178 In: W. F. Perrin, B. Wursig and J. G. M. Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, W. F., 2002e. Atlantic spotted dolphin. Pp. 49-51 In: W. F. Perrin, B. Wursig and J. G. M. Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin, W. F. and R. L. Brownell, Jr., 2002. Minke whales. Pp. 750-754 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Perrin W. F. and J. G. Mead, 1994. Clymene dolphin - *Stenella clymene*. Pp 161-172 In: SH Ridgway and SR Harrison (eds.), *Handbook of Marine Mammals* Vol. 5: The first book of dolphins. Academic Press, London.

Pitman, R. L., 2002b. Mesoplodont whales. Pp. 738-742 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Reeves, R. R., BS Stewart, PJ Clapham, and JA Powell, 2002. *National Audubon Society Guide to Marine Mammals of the World*. Alfred A Knopf: New York. 527 pp.

Reynolds, J. E. III and J. A. Powell, 2002. Manatees. Pp. 709-720 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Richard, K. R. and M. A. Barbeau, 1994. Observations of spotted dolphins feeding nocturnally on flying fish. *Marine Mammal Science* 10(4): 473-477.

Roberts, S. M., 2003. Examination of the stomach contents from a Mediterranean sperm whale found south of Crete, Greece. *J. Mar. Biol. Ass. U.K.* 83: 667-670.

Robertson, K. M. and S. J. Chivers, 1997. Prey occurrence in pantropical spotted dolphins, *Stenella attenuata*, from the eastern tropical Pacific. *Fishery Bulletin* 95(2): 334-348.

Rossbach, K. and D. Herzing, 1997. Underwater observations of benthic-feeding bottlenose dolphins (*Tursiops truncatus*) near Grand Bahama Island, Bahamas. *Marine Mammal Science* 13(3): 498-504.

Santos, R. A. and M. Haimovici, 2001. Cephalopods in the diet of marine mammals stranded or incidentally caught along southeastern and southern Brazil (21-34S). *Fisheries Research* 52(1-2): 99-112.

Santos, M. B., G. J. Pierce, J. Herman, A. Lopez, A. Guerra, E. Mente and M. R. Clarke, 2001. Feeding ecology of Cuvier's beaked whale (*Ziphius cavirostris*): a review with new information on the diet of this species. *Journal of the Marine Biological Association of the United Kingdom* 81: 687-694.

Saulitis, E., C. Matkin, L. Barrett-Lennard, K. Heise and G. Ellis, 2000. Foraging strategies of sympatric killer whale (*Orcinus orca*) populations in Prince William Sound, Alaska. *Marine Mammal Science* 16(1): 94-109.

Scott M. D., A. A. Hohn, A. J. Westgate, J. R. Nicolas, B. R. Whitaker and W. B. Campbell, 2001. A note on the release and tracking of a rehabilitated pygmy sperm whale (*Kogia breviceps*). *Journal of Cetacean Research and Management* 3:87-94.

Shane, S. H., R. S. Wells and B. Wursig, 1986. Ecology, behavior and social organization of the bottlenose dolphin: a review. *Marine Mammal Science* 2(1): 34-63.

Smith, S. C. and H. Whitehead, 2000. The diet of Galapagos sperm whales *Physeter macrocephalus* as indicated by fecal sample analysis. *Marine Mammal Science* 16(2): 315-325.

Soto, N. A., M. Johnson, P. T. Madsen, P. L. Tyack, A. Bocconcelli and J. F. Borsani, 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*)? *Marine Mammal Science* 22(3): 690-699.

Tiemann, C. O., A. M. Thode, J. Straley, V. O'Connell and K. Folkert, 2006. Three-dimensional localization of sperm whales using a single hydrophone. *J. Acoustical Soc. America* 120(4):2355-2365.

Tyack, P. L., M. Johnson, N. Aguilar Soto, A. Sturlese and P.T. Madsen, 2006. Extreme diving of beaked whales. *Journal of Experimental Biology* 209(21):4238-4253.

Wahlberg M., 2002. The acoustic behaviour of diving sperm whales observed with a hydrophone array. *Journal of Experimental Marine Biology & Ecology* 281:53-62.

Wang, M. C., W. A. Walker, K. T. Shao and L. S. Chou, 2003. Feeding habits of the pantropical spotted dolphin, *Stenella attenuata*, off the eastern coast of Taiwan. *Zoological Studies* 42(2): 368-378.

Waring, G. T., E. Josephson, C. P. Fairfield and K. Maze-Foley, 2007. US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments - 2006. NOAA Tech Memo NMFS-NE-201. Available from http://www.nmfs.noaa.gov/pr/sars/.

Watkins, W. A., M. A. Daher, N. A. DiMarzio, A. Samuels, D. Wartzok, K. M. Fristrup, P. W. Howey and R. R. Maiefski. 2002. Sperm whale dives tracked by radio tag telemetry. *Marine Mammal Science* 18(1): 55-68.

Watkins, W. A., M. A. Daher, K. Fristrup and G. Notarbartolo di Sciara. 1994. Fishing and acoustic behavior of Fraser's dolphin (*Lagenodelphins hosei*) near Dominica, southeast Caribbean. *Caribbean Journal of Science* 30 (1-2): 76-82.

Watkins, W. A., M. A. Daher, K. M. Fristrup, T. J. Howald and G. Notarbartolo di Sciara. 1993. Sperm whales tagged with transponders and tracked underwater by sonar. *Marine Mammal Science* 9: 55-67.

Watwood, S. L., P. J. O. Miller, M. Johnson, P. T. Madsen and P. L. Tyack. 2006. Deep-diving foraging behaviour of sperm whales (*Physeter macrocephalus*). *Journal of Ecology* 75: 814-825.

Weller, D. W., A. J. Schiro, V. G. Cockcroft and W. Ding. 1996. First account of a humpback whale (*Megaptera novaeangliae*) in Texas waters, with a re-evaluation of historical records from the Gulf of Mexico. *Marine Mammal Science* 12(1): 133-137.

Wells, R. S. and M. D. Scott. 2002. Bottlenose dolphins. Pp 122-128 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Whitehead, H.. 2002. Sperm whale. Pp. 1165-1172 In: WF Perrin, B Wursig and JGM Thewissen (eds) *Encyclopedia of Marine Mammals*. Academic Press: San Diego. 1414 pp.

Wynne, K. and M. Schwartz, 1999. *Guide to Marine Mammals and Turtles of the U.S. Atlantic and Gulf of Mexico*. Rhode Island Sea Grant, Narragansett, Rhode Island. 114 pp.

APPENDIX B

GEOGRAPHIC DESCRIPTION OF ENVIRONMENTAL PROVINCES

GEOGRAPHIC DESCRIPTION OF ENVIRONMENTAL PROVINCES

Propagation loss ultimately determines the extent of the zone of effect (ZOE) for a particular source activity. In turn, propagation loss as a function of range responds to a number of environmental parameters:

- Water depth
- Sound speed variability throughout the water column
- Bottom geo-acoustic properties, and
- Wind speed

Due to the importance that propagation loss plays in Anti-Submarine Warfare (ASW), the Navy has over the last four to five decades invested heavily in measuring and modeling these environmental parameters. The result of this effort is the following collection of global databases of these environmental parameters, most of which are accepted as standards for all Navy modeling efforts.

- Water depth – Digital Bathymetry Data Base Variable Resolution (DBDBV)
- Sound speed – Generalized Digital Environmental Model (GDEM)
- Bottom loss – Low-Frequency Bottom Loss (LFBL), Sediment Thickness Database, and High-Frequency Bottom Loss (HFBL), and
- Wind speed – United States (U.S.) Navy Marine Climatic Atlas of the World

This section provides a discussion of the relative impact of these various environmental parameters. These examples then are used as guidance for determining environmental provinces (that is, regions in which the environmental parameters are relatively homogenous and can be represented by a single set of environmental parameters) within the Naval Surface Warfare Center, Panama City Division (NSWC PCD) Study Area.

B.1 IMPACT OF ENVIRONMENTAL PARAMETERS

Within a typical operating area (OPAREA), bathymetry is the environmental parameter that tends to vary the most. It is not unusual for water depths to vary by an order of magnitude or more, resulting in a significant impact upon the ZOE calculations. Bottom loss can also vary considerably over typical OPAREAS, but its impact upon ZOE calculations tends to be limited to waters on the continental shelf and the upper portion of the slope. Generally, the primary propagation paths in deep water from the source to most of the ZOE volume do not involve any interaction with bottom. In shallow water, particularly if the sound velocity profile directs all propagation paths to interact with the bottom, bottom loss variability can play a large role.

The spatial variability of the sound speed field is generally small over OPAREAS of typical size. The presence of a strong oceanographic front is a noteworthy exception to this rule. To a lesser extent, variability in the depth and strength of a surface duct can be of some importance. In the mid latitudes, seasonal variation often provides the most significant variation in the sound speed field. For this reason, both summer and winter profiles are modeled for each selected environment.

B.2 ENVIRONMENTAL PROVINCING METHODOLOGY

The underwater acoustic environment can be quite variable over ranges in excess of 10 kilometers (km) (6.2 miles [mi]). For the NSWC PCD Research, Development, Test, and Evaluation (RDT&E) applications, ranges of interest are often sufficiently large as to warrant the modeling of the spatial variability of the environment. In the propagation loss calculations, each of the environmental parameters is allowed to vary (either continuously or discretely) along the path from acoustic source to receiver. In such applications, each propagation loss calculation is conditioned upon the particular locations of the source and receiver.

On the other hand, the range of interest for marine animal harassment by most Naval activities is more limited. This reduces the importance of the exact location of source and marine animal, and makes the modeling required more manageable in scope.

In lieu of trying to model every environmental profile that can be encountered in an OPAREA, this effort utilizes a limited set of representative environments. Each environment is characterized by a fixed water depth, sound velocity profile, and bottom loss type. The operating area is then partitioned into homogeneous regions (or provinces) and the most appropriately representative environment is assigned to each. This process is aided by some initial provincing of the individual environmental parameters. The Navy-standard high-frequency bottom loss database in its native form is globally partitioned into nine classes. (Low-frequency bottom loss is likewise provinced in its native form, although it is not considered in this selection of environmental provinces. The sources for which low-frequency bottom loss would be of interest have limited impact ranges thus rendering bottom loss of little consequence in this analysis.) The Navy-standard sound velocity profiles database is also available as a provinced subset. Only the Navy-standard bathymetry database varies continuously over the world's oceans. However, even this environmental parameter is easily provinced by selecting a finite set of water depth intervals. "Octave-spaced" intervals (10, 20, 50, 100, 200, 500, 1,000, 2,000, and 5,000 meters (m) or 33, 66, 164, 328, 656, 1,640, 3,281, 6,562, and 16,404 feet [ft]) provide an adequate sampling of water depth dependence.

ZOE volumes are then computed using propagation loss estimates derived for the representative environments. Finally, a weighted average of the ZOE volumes is taken over all representative environments; the weighting factor is proportional to the geographic area spanned by the environmental province.

The selection of representative environments is subjective. However, the uncertainty introduced by this subjectivity can be mitigated by selecting more environments and by selecting the environments that occur most frequently over the OPAREA of interest.

As discussed in the previous subsection, ZOE estimates are most sensitive to water depth. Unless otherwise warranted, at least one representative environment is selected in each bathymetry province. Within a bathymetry province, additional representative environments are selected as needed to meet the following requirements:

- In shallow water (less than 1,000 m [3,281 ft]), bottom interactions occur at shorter ranges and more frequently, thus significant variations in bottom loss need to be represented.
- Surface ducts provide an efficient propagation channel that can greatly influence ZOE estimates. Variations in the mixed layer depth need to be accounted for if the water is deep enough to support the full extent of the surface duct.

Depending upon the size and complexity of the OPAREA, the number of environmental problems tends to range from 5 to 20.

B.2.1 Description of Environmental Provinces Used in Acoustic Modeling

This section describes the representative environmental provinces selected for the entire NSWC PCD Study Area. The narrowband sources described in Appendix M are, for the most part, deployed throughout the NSWC PCD Study Area. The broadband sources are primarily limited to portions of the continental shelf. For all of these provinces, the average winter wind speed is 14 knots (16 miles per hour [mi/hr]) and the average summer wind speed is 9 knots (10 mi/hr).

The NSWC PCD Study Area contains a total of 16 distinct environmental provinces. These represent the various combinations of eight bathymetry provinces, one Sound Velocity Profile (SVP) provinces, three LFBL geoacoustic provinces, and two HFBL classes. The bathymetry provinces represent depths ranging from 5 m (16 ft) to more than a kilometer (0.6 miles). Nearly three-fourths of the NSWC PCD Study Area is located on the continental shelf in waters less than 200 m (656 ft). The distribution of the bathymetry provinces over the entire NSWC PCD Study Area is provided in Table B-1.

Table B-1. Distribution of Bathymetry Provinces in the NSWC PCD Study Area

Province Depth (m) (ft)	Frequency of Occurrence
5 (16)	3.03 %
10 (33)	3.00 %
20 (66)	12.48 %
40 (131)	16.88 %
80 (262)	14.21 %
160 (525)	23.63 %
320 (1,050)	22.39 %
640 (2,100)	4.38 %

m = meters; ft - feet

A single SVP province includes the entire NSWC PCD Study Area. The seasonal variation is somewhat limited in its dynamic range, as might be expect given that the range is located in temperate waters. The winter profile’s surface sound speed profile is about 25 meters per second (m/sec) (56 mi/hr) slower than the summer profile, as depicted in Figure B-1, and features a 50 m (164 ft) surface duct.

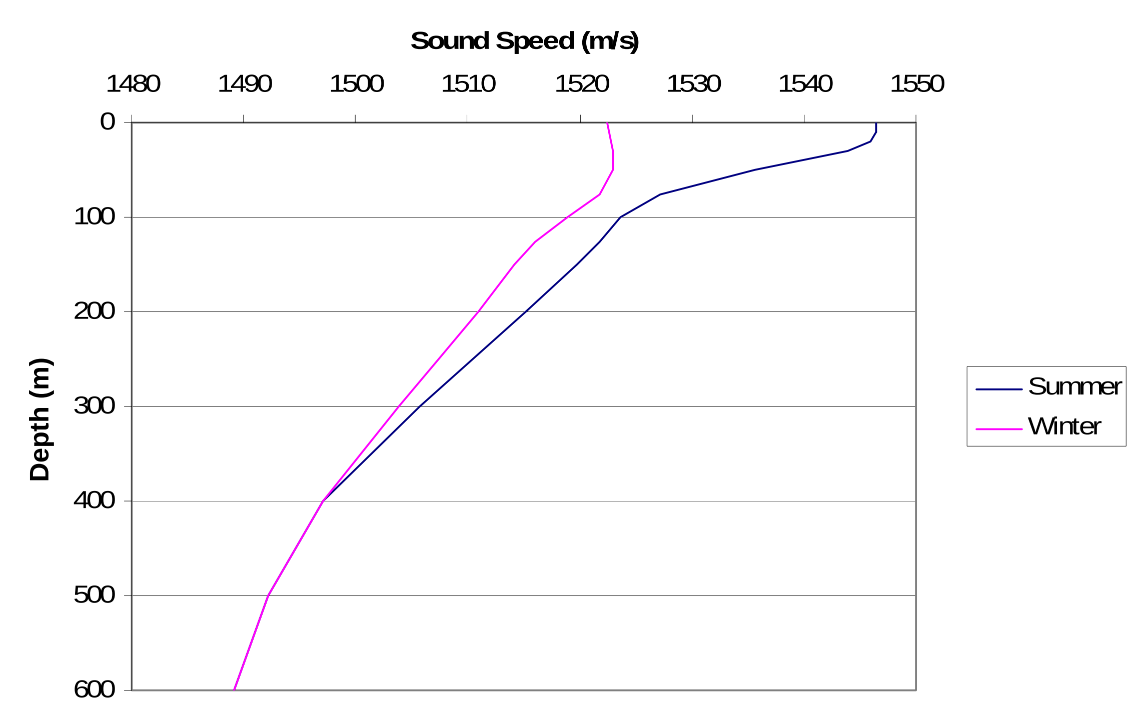


Figure B-1. Winter and Summer SVPs in the NSWC PCD Study Area

The two HFBL classes represented in the NSWC PCD Study Area are low-loss bottom (class 2, typically found in shallow water) and high-loss bottom (class 8). The distribution presented in Table B-2 indicates that the high-loss bottom dominates.

Table B-2. Distribution of Sound Speed Provinces in the NSWC PCD Study Area

HFBL Class	Frequency of Occurrence
2	28.97 %
8	71.03 %

The variation in sound speed profiles among the three provinces is quite minimal; indeed, due to the tropical location even the seasonal variability is quite small. This is illustrated in Figure B-1, which displays the upper 1,000 m (3,281 ft) of the winter and summer profiles.

The three LFBL provinces represented in the NSWC PCD Study Area have densities ranging from coarse sand to clayey silt. Their distribution is identified in Table B-3.

Table B-3. Distribution of Low-Frequency Bottom Loss Classes in the NSWC PCD Study Area

HFBL Class	Frequency of Occurrence
Coarse Sand	66.39
Fine Sand	7.27
Clayey Silt	26.34

Table B-4. Distribution of Environmental Provinces in the NSWC PCD Study Area

Environmental Province	Water Depth (m) (ft)	HFBL Class	LFBL Province	Sediment Thickness	Frequency of Occurrence
1	5 (16)	2	0	0.2 secs	3.03 %
2	10 (33)	2	0	0.2 secs	3.00 %
3	20 (66)	2	0	0.2 secs	12.48 %
4	40 (131)	2	0	0.2 secs	14.44 %
5	80 (262)	2	– 49*	0.57 secs	0.46 %
6	320 (1050)	2	0	0.95 secs	4.54 %
7	640 (2100)	2	– 49*	0.2 secs	4.37 %
8	40 (131)	2	– 49*	0.2 secs	2.36 %
9	80 (262)	2	13	0.2 secs	12.13 %
10	160 (525)	2	13	0.2 secs	14.20 %
11	320 (1050)	2	13	0.2 secs	0.01 %
12	40 (131)	8	– 49*	0.2 secs	0.08 %
13	80 (262)	8	0	0.2 secs	1.62 %
14	160 (525)	8	0	0.2 secs	9.43 %
15	320 (1050)	8	0	0.2 secs	17.83 %
16	640 (2100)	8	0	0.2 secs	0.01 %

* Negative numbers indicate provinces that were developed as part of the Shallow-Water Upgrade to the LFBL database. These provinces are primarily limited to water depths between 50-800 m (164–2,625 ft) in the Gulf of Mexico (GOM), but do not necessarily cover all such areas.

The logic for consolidating the environmental provinces focuses upon water depth, using bottom type as secondary differentiating factors. The first consideration is to ensure that all eight bathymetry provinces are represented. Environmental provinces that occur in less than one percent of the NSWC PCD Study Area are consolidated with similar provinces (using water depth first and then HFBL as the rules for consolidation). Next, any remaining small province that has a reasonable proxy (that is, the same water depth and HFBL province) is consolidated with its comparable province. This results in the following mapping of raw environmental provinces into an initial subset:

Raw Province	Subset Province
5	9
8	4
11	6
12	4
16	7

The resulting distribution of the eleven environmental provinces used to model the narrowband sources in the NSWC PCD Study Area modeling is described in Table B-5.

The percentages given in the preceding table indicate the frequency of occurrence of each environmental province across all three Warning Areas in the NSWC PCD Study Area.

Table B-5. Distribution of Environmental Provinces in the NSWC PCD Study Area

Environmental Province	Water Depth (m) (ft)	HFBL Class	LFBL Province	Sediment Thickness	Frequency of Occurrence
1	5 (16)	2	0	0.2 secs	3.03 %
2	10 (33)	2	0	0.2 secs	3.00 %
3	20 (66)	2	0	0.2 secs	12.48 %
4	40 (131)	2	0	0.2 secs	16.88 %
6	320 (1,050)	2	0	0.95 secs	4.55 %
7	640 (2,100)	2	– 49*	0.2 secs	4.38 %
9	80 (262)	2	13	0.2 secs	12.59 %
10	160 (525)	2	13	0.2 secs	14.20 %
13	80 (262)	8	0	0.2 secs	1.62 %
14	160 (525)	8	0	0.2 secs	9.43 %
15	320 (1,050)	8	0	0.2 secs	17.83 %

* Negative numbers indicate provinces that were developed as part of the Shallow-Water Upgrade to the LFBL database. These provinces are primarily limited to water depths between 50-800 m in the GOM, but do not necessarily cover all such areas

Finally, all explosive sources are limited to environmental provinces that are situated on the continental shelf. The MK-58 line array is restricted even further to just the surf zone (nominally taken to be at a water depth of 2 m [6 ft]). This limits the modeling to a single environment that is identical to province 1 with the exception that the water depth is only 2 m (6 ft). The remaining mines are restricted to regions that are outside the 22 km (12 nautical miles [NM]) territorial limit. The 4.5 kilogram (kg) (10 pounds [lbs]) mines are detonated in water depths ranging from 30 m to 305 m (100 to 1,000 ft); 34 kg (75 lbs) mines in water depths ranging from 46 m to 61 m (150 to 200 ft); 200 kg (440 lbs) mines in water depths less than 100 m (328 ft); and 272 kg (600 lbs) mines in water depths ranging from 37 to 46 m (120 to 150 ft). The distribution of the environments used for each of these explosives is provided in Table B-6.

Table B-6. Distribution of Environmental Provinces for Explosive Sources in the NSWC PCD Study Area

Environmental Province	10# Mine	75# Mine	440# Mine	600# Mine	M-58 Line Charge
1 (2 m deep)	0.00 %	0.00 %	0.00 %	0.00 %	100.00 %
4	21.89 %	100.00 %	54.29 %	100.00 %	0.00 %
6	5.90 %	0.00 %	0.00 %	0.00 %	0.00 %
9	16.33 %	0.00 %	40.50 %	0.00 %	0.00 %
10	18.42 %	0.00 %	0.00 %	0.00 %	0.00 %
13	2.10 %	0.00 %	5.21 %	0.00 %	0.00 %
14	12.23 %	0.00 %	0.00 %	0.00 %	0.00 %
15	23.13 %	0.00 %	0.00 %	0.00 %	0.00 %

APPENDIX C

DEFINITIONS AND METRICS FOR ACOUSTIC QUANTITIES

“

DEFINITIONS AND METRICS FOR ACOUSTIC QUANTITIES

This appendix provides reference materials on some of the more important metrics and units used in the report. It is intended to provide basic information, with references to further information.

C.1 SOME FUNDAMENTAL DEFINITIONS OF ACOUSTICS

Sound and Acoustics

Paraphrasing Beranek (1986), *sound* is defined as a disturbance propagated through an elastic medium, causing a change in pressure or a displacement of particles.

Sound is produced when an elastic medium is set into motion, often by a vibrating object within the medium. As the object vibrates, its motion is transmitted to adjacent "particles" of the medium. The motion of these particles is transmitted to adjacent particles, and so on. The result is a mechanical disturbance (the "sound wave") that moves away from the source and propagates at a medium-dependent speed (the "sound speed"). As the sound wave travels through the medium, the individual particles of the medium oscillate about their static positions but do not propagate with the sound wave. As the particles of the medium move back and forth they create small changes, or perturbations, about the static values of the medium density, pressure, and temperature.

Density

For a static, homogeneous volume of matter, *density* is the mass per unit volume. In seawater, the average density is about 1026 kilogram per cubic meter (kg/m^3) (2,262 lbs per 35.3 cubic feet), or 1.026 gram per cubic centimeter (g/cm^3) (.036 ounces per .061 cubic inch). In air, density varies substantially with altitude and with time. A typical value at sea level and 20 degrees Celsius (°C) (68 degrees Fahrenheit [°F]) is 1.21 kg/m^3 (2.67 lbs per .061 cubic inch) or 0.00121 g/cm^3 (4.27e-5 ounce per .061 cubic inch).

Pressure

Pressure (in mechanics) is a type of stress that is exerted uniformly in all directions; its measure is the force exerted per unit area (MHDPM, 1978).

In a fluid (gas or liquid), *pressure at a point* is defined as follows. For an arbitrarily small area containing the point, the pressure is the normal force applied to the small area divided by the size of the small area.

Static Pressure (in acoustics) is, at a point in a fluid (gas or liquid), the pressure that would exist if there were no sound waves present (Beranek, 1986).

Because pressure is a force applied to a unit area, it does not necessarily generate energy. Pressure is a scalar quantity; there is no direction associated with pressure, though a pressure wave may have a direction of propagation. *Pressure* has units of force/area. The source intensity (SI) derived unit of pressure is the Pascal (Pa) defined as one newton per square meter (N/m^2). Alternative units are many (pounds per square feet [lbs/ft^2], bars, inches of mercury, etc.); some are listed at Section C.4 of this appendix.

Acoustic Pressure

Without limiting the discussion to small amplitude or linear waves, *acoustic pressure* is defined as the residual pressure over the "average" static pressure caused by a disturbance. As such, the "average" acoustic pressure is zero. Here the "average" is usually taken over time.

Mean-Square Pressure is usually defined as the short-term time average of the squared pressure:

$$\frac{1}{T}\int_{\tau}^{\tau+T} p^2(t)dt\,,$$

where *T* is on the order of several periods of the lowest frequency component of the time series.

Root Mean Square (RMS) Pressure is the square root of the mean-square pressure.

Impedance

In general *impedance* measures the ratio of force amplitude to velocity amplitude. For plane waves, the ratio is ρc, where ρ is the fluid density and *c* the sound speed.

Equivalent Plane Wave Intensity

As noted by Bartberger (1965) and others, it is general practice to measure (and model) pressure (p) or rms pressure (p_{rms}), and then infer an intensity from the formula for plane waves in the direction of propagation:

Intensity = $(p_{rms})^2/\rho c$.

Such an inferred intensity should properly be labeled as the *equivalent plane-wave intensity in* the *propagation direction*.

Energy Flux Density (EFD)

Sound energy can be described by the sound energy flux density (EFD), which is the sound power flow per unit area, or the time integral of instantaneous intensity. For plane waves,

$$EFD = \frac{1}{\rho c}\int_{0}^{T} p^2(t)dt,$$

where ρc is the impedance and *t* is the duration of the signal. Units are Joule per square meter (J/m^2). Note that EFD is the time-averaged squared pressure multiplied by the averaging time.

C.2 DEFINITIONS RELATED TO SOUND SOURCES, SIGNALS, AND EFFECTS

Source Intensity

S*ource intensity,* $I(\theta,\phi)$, is the intensity of the projected signal referred to a point at unit distance from the source in the direction (θ,ϕ). (θ,ϕ) is usually unstated; in that case, it is assumed that propagation is in the direction of the axis of the main lobe of the projector's beam pattern.

Source Power

For an omni-directional source, the power radiated by the projector at range *r* is $I_r(4\pi r^2)$ where I_r is the radiated intensity at range *r* (in the far field). If intensity has SI units of watts per square meter (W/m^2), then the power has units of *W*. The result can be extrapolated to a unit reference distance if either I_1 is known or $I_r=I_1/r^2$. Then the *source power* at unit distance is $4\pi I_1$, where I_1 is the intensity (any direction) at unit distance in units of power/area.

Pure Tone Signal or Wave (related: Continuous Wave, CW, Monochromatic Wave, Unmodulated Signal)

Each term means a single-frequency wave or signal, but perhaps limited in time (gated). The actual bandwidth of the signal will depend on duration and context.

Narrowband Signal

Narrowband is a non-precise term. It is used to indicate that the signal can be treated as a single-frequency carrier signal, which is made to vary (is modulated) by a second signal whose bandwidth is smaller than the carrier frequency. In dealing with sonars, a bandwidth less than about 30 percent of center frequency is often spoken of as narrowband.

Hearing Threshold

"The *threshold of hearing* is defined as the sound pressure at which one, listening with both ears in a free field to a signal of waning level, can still just hear the sound, or if the signal is being increased from a level below the threshold, can just sense it" (Magrab, p. 29, 1975).

"A threshold of audibility for a specified signal is the minimum effective sound pressure of that signal that is capable of evoking an auditory sensation (in the absence of noise) in a specified fraction of trials" (Beranek, p. 394, 1986).

Temporary (Hearing) Threshold Shift (TTS)

"The diminution, following exposure to noise, of the ability to detect weak auditory signals is termed *temporary threshold shift* (TTS), if the decrease in sensitivity eventually disappears…" (Magrab, p. 35, 1975).

Permanent (Hearing) Threshold Shift (PTS)

"The diminution, following exposure to noise, of the ability to detect weak auditory signals is termed temporary threshold shift (TTS), if the decrease in sensitivity eventually disappears, and noise-induced permanent threshold shift (NIPTS) if it does not" (Magrab, p. 35, 1975).

C.3 DECIBELS AND SOUND LEVELS

Decibel (dB)

Because practical applications of acoustic power and energy involve wide dynamic ranges (e.g., from 1 to 1,000,000,000,000), it is common practice to use the logarithm of such quantities. The use of a logarithmic scale compresses the range of numerical values that must be used. For a given quantity Q, define the decibel as:

$$10 \, log \, (Q/Q_0) \text{ dB re } Q_0$$

where Q_0 is a reference quantity and *log* is the base-10 logarithm.

When a numeric value is presented in decibels, it is important to also specify the numeric value and units of the reference quantity. Normally the numeric value is given, followed by the text "re", meaning "with reference to", and the numeric value and unit of the reference quantity (Harris, 1998). For example, a pressure of 1 Pa, expressed in decibels with a reference of 1 µPa, is written 120 dB re 1 µPa.

The word "level" usually indicates decibel quantity (e.g., *sound pressure level* or *spectrum level*). Some specific examples for this document follow.

Sound Pressure Level

For pressure p, the *sound pressure level* (SPL) is defined as follows:

$$\text{SPL} = 10 \log (p^2/p_0{}^2) \text{ dB re 1 } p_0{}^2,$$

where p_0 is the reference pressure (usually 1 µPa for underwater acoustics and 20 µPa for in-air acoustics). The convention is to state the reference as p_0 (with the square implicit).

For a pressure of 100 µPa, the SPL would be

$$10 \log [(100 \text{ µPa})^2/ (1 \text{ µPa})^2] \text{ dB re 1 µPa}$$

$$= 40 \text{ dB re 1 µPa}$$

This is about the lowest level that a dolphin can hear in water.

Source Level

Refer to source intensity above. Define *source level* as $SL(\theta,\phi) = 10 \log[I(\theta,\phi)/I_0]$, where I_o is the reference intensity (usually that of a plane wave of rms pressure 1 μPa). The reference pressure and reference distance must be specified. When SL does not depend on direction, then the source is said to be *omnidirectional;* otherwise it is *directive.*

Intensity Level

It is nearly universal practice to use SPL in place of intensity level. This makes sense as long as impedance is constant. In that case, intensity is proportional to short-term-average, squared pressure, with proportionality constant equal to the reciprocal of the impedance.

When the impedance differs significantly in space or time (as in noise propagation from air into water), the intensity level must specify the medium change and/or the changes in impedance.

Intensity Levels in Water and in Air as Functions of Pressure and SPL

Unlike pressure, the metrics for intensity depend on the acoustic impedance of the medium. Thus, for example, under the assumption of plane waves, the same pressure (first three columns) causes different intensities in water and in air:

Pressure (rms)	**SPL (re 1 μPa)**	**SPL (re 20 μPa)**	**Intensity in Water (W/m^2)**	**Intensity in Air (W/m^2)**
1 μPa = 10^{-5} dyn/cm^2	0 dB	-26 dB	$6.7\ 10^{-19}$	$2.4\ 10^{-15}$
20 μPa = 0.0002 μbar	26 dB	0 dB	$2.7\ 10^{-16}$	$9.6\ 10^{-13}$
$1.2\ 10^{9}$ μPa = 1.2 kPa	181.8 dB	155.8 dB	1	3600
1 psi = $6.9\ 10^{9}$ μPa	196.8 dB	170.8 dB	31.8	$1.1\ 10^{5}$
$1.77\ 10^{10}$ μPa	205 dB	179.0 dB	252.6	$8.7\ 10^{5}$
$3.2\ 10^{10}$ μPa = 66.7 psf	210 dB	184 dB	660.7	$2.4\ 10^{6}$
$3.2\ 10^{12}$ μPa = 3200 kPa	250 dB	224 dB	$6.6\ 10^{6}$	$2.4\ 10^{10}$

rms = root mean square; SPL = sound pressure level; W/m^3 = Watts per square meter; psi = pounds per square inch; μPa = micropascals; kPa = kilopascals; dB = decibels; psf = pounds per square foot

Energy (Flux Density) Level (EFDL) Referred to $Pressure^2$ Time

Note that the abbreviation "EFDL" is not in general usage, but is used here for convenience.

Just as the usual reference for intensity level is pressure (and not intensity itself), the reference often (but not always) used for EFDL is *$pressure^2$ time*. This makes sense when the impedance is constant. Some examples of conversions follow:

Suppose the integral of the plane-wave pressure-squared time is 1 μPa^2-s. Since impedance for water is $1.5\ 10^{12}$ μPa(s/m), the EFD is then

$$(1\ \mu Pa^2\text{-s})/(1.5\ 10^{12}\ \mu Pa(s/m)) = 6.66\ 10^{-13}\ \mu Pa\text{-m} = 6.66\ 10^{-19}\ J/m^2$$

Thus an EFDL of 0 dB (re 1 μPa^2-s) corresponds to an EFD of $6.66\ 10^{-19}$ J/m^2 (in water).

It follows that thresholds of interest for impacts on marine life have values in water as follows:

190 dB (re 1 μPa^2-s) = 10^{19} x 6.66 10^{-19} J/m^2 = 6.7 J/m^2
195 dB (re 1 μPa^2-s) = 21.2 J/m^2
200 dB (re 1 μPa^2-s) = 66.7 J/m^2
205 dB (re 1 μPa^2-s) = 210.6 J/m^2
215 dB (re 1 μPa^2-s) = 2106.1 J/m^2

Given that 1 J = 1 Ws, notice that these energies are small. Applied to an area the size of a person, 215 dB would yield about 2000 J, or about 2 kWs or about .0006 kW-hr.

C.4 SOME CONSTANTS AND CONVERSION FORMULAS

Speed of Sound in Water (c_w)

The speed of sound in water varies no more than 3 percent over geographic area, depth and season. For rough estimates of impedance and travel time, nominal values of 1,500 meters per second (m/sec) and 5,000 feet per second (ft/s) are often used.

Typical Density and Sound Speed of Sea Water

Water Density (4°C) = $\rho_w \approx$ 1 g/cm^3 = 10^3 kg/m^3 $\approx$ 1.94 $slug/ft^3$ $\approx$ 62.43 lb (mass)/ft^3

Sound Speed = $c_w \approx$ 1500 m/s = 1.5 10^5 cm/s $\approx$ 4920 ft/s $\approx$ 59040 in/s

Characteristic Impedance of Water

$\rho_w c_w \approx$ 1.5 10^6 kg/s m^2 = 1.5 10^6 rayl = 1.5 10^5 g/s cm^2
= 1.5 10^{12} µPa (s/m) = 1.5 10^5 (dyn/cm^2)(s/cm) $\approx$ 9544.8 $slugs/ft^2$ s
$\approx$ 3.072 10^5 lb(mass)/ft^2 s

Length
1 NM = 1.85325 km
1 m = 3.2808 ft

Speed
1 knot = 0.514791 m/sec = 1.85325 km/hr
1 m/sec= 3.2808 ft/s = 196.85 ft/min
1 m/sec = 1.94254 knots

Pressure
1 Pa = 1 N/m^2 = 1 J/m^3 = 1 kg/m s^2
1 Pa = 10^6 µ Pa = 10 dyn/cm^2 = 10 µbar
1 µPa = 10^{-5} dyn/cm^2 = $1.4504 \cdot 10^{-10}$ psi
1 kPa = 1000 Pa = 10^9 µPa = 0.145 psi = 20.88 psf

Power
1 W = 1 J/s = 1 Nm/s = 1 kg m^2/s^2
1 W = 10^7 erg/s

<u>Energy (Work)</u>

1 J = 1 N m = 1 kg m^2/s^2
1 J= 10^7 g cm^2/s^2 = 1 W s
1 erg = 1 g cm^2/s^2 = 10^{-7} J
1 kW hr = (3.6) 10^6 J

<u>Acoustic Intensity</u>

1 W/m^2= 1 Pa (m/sec) = 10^6 μPa (m/sec)
1 W/m^2= 1 J/(s m^2) = 1 N/m s
1 psi in/s = 175 W/m^2 = 1.75 10^8 μPa (m/sec)
1 lb/ft s = 14.596 J/m^2s = 14.596 W/m^2
1 W/m^2 = 10^7 erg/m^2s = 10^3 erg/cm^2s

<u>Acoustic Energy Flux Density</u>

1 J/m^2 = 1 N/m = 1 Pa m = 10^6 μPa m = 1 W s/m^2
1 J/m^2 = 5.7 10^{-3} psi in = 6.8 10^{-2} psf ft
1 J/cm^2 = 10^4 J/m^2 = 10^7 erg/cm^2
1 psi in = 175 J/m^2 = 1.75 10^8 μPa m

C.5 REFERENCES

Au, W. W. L., 1993. *The Sonar of Dolphins*, Springer-Verlag, New York.

Bartberger, C. L., Lecture Notes on Underwater Acoustics, NADC Report NADC-WR-6509, Naval Air Development Center, Johnsville, PA, May 17, 1965 (AD 468 869).

Beranek, L. L., 1986. *Acoustics*, American Institute of Physics, Inc., New York.

Crocker, M. J., 1997. Editor, *Encyclopedia of Acoustics*, John Wiley & Sons, Inc., New York.

Ewing, W. M., W. S. Jardetzky, and F. Press, 1957. *Elastic Waves in Layered Media*, McGraw-Hill Book Company, New York.

Fahy, F. J., 1995. *Sound Intensity*. E&FN Spon, London.

Harris, C. M. (1998). “Introduction,” in Handbook of Acoustical Measurements and Noise Control, 3rd edition (Acoustical Society of America, NY).

Kinsler, L E. and A. R. Frey, 1962. *Fundamentals of Acoustics*. John Wiley and Sons, New York.

Magrab, E. B., 1975. *Environmental Noise Control*, John Wiley and Sons, New York.

McGraw-Hill Dictionary of Physics and Mathematics (MHDPM), 1978. D. N. Lapedes (Editor in Chief), McGraw-Hill Book Company, New York.

Pierce, A. D., 1989. *Acoustics, An Introduction to Its Physical Principles and Applications*, Acoust. Soc. Am., Woodbury, NY.

Richardson, W. J, C. R. Green, Jr., C. I. Malme, and D. H. Thomson, 1995. *Marine Mammals and Noise*, Academic Press, Inc., San Diego, CA.

Ross, D., 1987. *Mechanics of Underwater Noise*, Peninsula Publishing, Los Altos, CA.

Urick, R. J., 1975 and 1983. *Principles of Underwater Sound*. McGraw-Hill, New York.

Yost, W. A. and M. Killion, 1997. Hearing Thresholds, in Crocker, 1997.

1

This page is intentionally blank.

APPENDIX D

MARINE MAMMAL STRANDING REPORT

WHAT IS A STRANDED MARINE MAMMAL?

When a live or dead marine mammal swims or floats onto shore and becomes "beached" or incapable of returning to sea, the event is termed a "stranding" (Geraci et al., 1999; Perrin and Geraci, 2002; Geraci and Lounsbury, 2005; NMFS, 2007). The legal definition for a stranding within the U.S. is that "a marine mammal is dead and is (i) on a beach or shore of the United States; or (ii) in waters under the jurisdiction of the United States (including any navigable waters); or (B) a marine mammal is alive and is (i) on a beach or shore of the United States and is unable to return to the water; (ii) on a beach or shore of the United States and, although able to return to the water, is in need of apparent medical attention; or (iii) in the waters under the jurisdiction of the United States (including any navigable waters), but is unable to return to its natural habitat under its own power or without assistance." (16 United States Code [U.S.C.] 1421h).

The majority of animals that strand are dead or moribund (NMFS, 2007). For animals that strand alive, human intervention through medical aid and/or guidance seaward may be required for the animal to return to the sea. If unable to return to sea, rehabilitation at an appropriate facility may be determined as the best opportunity for animal survival. An event where animals are found out of their normal habitat is may be considered a stranding depending on circumstances even though animals do not necessarily end up beaching (Southhall, 2006).

Three general categories can be used to describe strandings: single, mass, and unusual mortality events. The most frequent type of stranding is a single stranding, which involves only one animal (or a mother/calf pair) (NMFS, 2007).

Mass stranding involves two or more marine mammals of the same species other than a mother/calf pair (Wilkinson, 1991), and may span one or more days and range over several miles (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Walsh et al., 2001; Freitas, 2004). In North America, only a few species typically strand in large groups of 15 or more and include sperm whales, pilot whales, false killer whales, Atlantic white-sided dolphins, white-beaked dolphins, and rough-toothed dolphins (Odell 1987, Walsh et al. 2001). Some species, such as pilot whales, false-killer whales, and melon-headed whales occasionally strand in groups of 50 to 150 or more (Geraci et al. 1999). All of these normally pelagic off-shore species are highly sociable and usually infrequently encountered in coastal waters. Species that commonly strand in smaller numbers include pygmy killer whales, common dolphins, bottlenose dolphins, Pacific white-sided dolphin Frasier's dolphins, gray whale and humpback whale (West Coast only), harbor porpoise, Cuvier's beaked whales, California sea lions, and harbor seals (Mazzuca et al. 1999, Norman et al. 2004, Geraci and Lounsbury 2005).

Unusual mortality events (UMEs) can be a series of single strandings or mass strandings, or unexpected mortalities (i.e., die-offs) that occur under unusual circumstances (Dierauf and Gulland, 2001; Harwood, 2002; Gulland, 2006; NMFS, 2007). These events may be interrelated: for instance, at-sea die-offs lead to increased stranding frequency over a short period of time, generally within one to two months. As published by NMFS, revised criteria for defining a UME include (Hohn et al., 2006b):

(1) A marked increase in the magnitude or a marked change in the nature of morbidity, mortality, or strandings when compared with prior records.

(2) A temporal change in morbidity, mortality, or strandings is occurring.

(3) A spatial change in morbidity, mortality, or strandings is occurring.

(4) The species, age, or sex composition of the affected animals is different than that of animals that are normally affected.

(5) Affected animals exhibit similar or unusual pathologic findings, behavior patterns, clinical signs, or general physical condition (e.g., blubber thickness).

(6) Potentially significant morbidity, mortality, or stranding is observed in species, stocks or populations that are particularly vulnerable (e.g., listed as depleted, threatened or endangered or declining). For example, stranding of three or four right whales may be cause for great concern whereas stranding of a similar number of fin whales may not.

(7) Morbidity is observed concurrent with or as part of an unexplained continual decline of a marine mammal population, stock, or species.

UMEs are usually unexpected, infrequent, and may involve a significant number of marine mammal mortalities. As discussed below, unusual environmental conditions are probably responsible for most UMEs and marine mammal die-offs (Vidal and Gallo-Reynoso, 1996; Geraci et al., 1999; Walsh et al., 2001; Gulland and Hall, 2005).

D.1 UNITED STATES STRANDING RESPONSE ORGANIZATION

Stranding events provide scientists and resource managers information not available from limited at-sea surveys, and may be the only way to learn key biological information about certain species such as distribution, seasonal occurrence, and health (Rankin, 1953; Moore et al., 2004; Geraci and Lounsbury, 2005). Necropsies are useful in attempting to determine a reason for the stranding, and are performed on stranded animals when the situation and resources allow.

In 1992, Congress passed the Marine Mammal Health and Stranding Response Act (MMHSRA) which authorized the Marine Mammal Health and Stranding Response Program (MMHSRP) under authority of the Department of Commerce, National Marine Fisheries Service. The MMHSRP was created out of concern started in the 1980s for marine mammal mortalities, to formalize the response process, and to focus efforts being initiated by numerous local stranding organizations and as a result of public concern.
Major elements of the MMHSRP include (NMFS, 2007):

- National Marine Mammal Stranding Network
- Marine Mammal UME Program
- National Marine Mammal Tissue Bank (NMMTB) and Quality Assurance Program
- Marine Mammal Health Biomonitoring, Research, and Development
- Marine Mammal Disentanglement Network
- John H. Prescott Marine Mammal Rescue Assistance Grant Program (a.k.a. the Prescott Grant Program)

- Information Management and Dissemination.

The United States has a well-organized network in coastal states to respond to marine mammal strandings. Overseen by NMFS, the National Marine Mammal Stranding Network is comprised of smaller organizations manned by professionals and volunteers from nonprofit organizations, aquaria, universities, and state and local governments trained in stranding response. Currently, more than 400 organizations are authorized by NMFS to respond to marine mammal strandings (NMFS, 2007).

- NMFS Regions and Associated States and Territories
- NMFS Northeast Region- ME, NH, MA, RI, CT, NY, NJ, PA, DE, MD, VA
- NMFS Southeast Region- NC, SC, GA, FL, AL, MS, LA, TX, PR, VI
- NMFS Southwest Region- CA
- NMFS Northwest Region- OR, WA
- NMFS Alaska Region- AK
- NMFS Pacific Islands Region- HI, Guam, American Samoa, Commonwealth of the Northern Mariana Islands (CNMI)

Stranding reporting and response efforts over time have been inconsistent, although effort and data quality within the U.S. have been improving within the last 20 years (NMFS, 2007). Given the historical inconsistency in response and reporting, however, interpretation of long-term trends in marine mammal stranding is difficult (NMFS, 2007). During the past decade (1995 – 2004), approximately 40,000 stranded marine mammals have been reported by the regional stranding networks, averaging 3,600 strandings reported per year (NMFS, 2007). The highest number of strandings were reported between the years 1998 and 2003 (NMFS, 2007). Detailed regional stranding information including most commonly stranded species can be found in Zimmerman (1991), Geraci and Lounsbury (2005), and NMFS (2007).

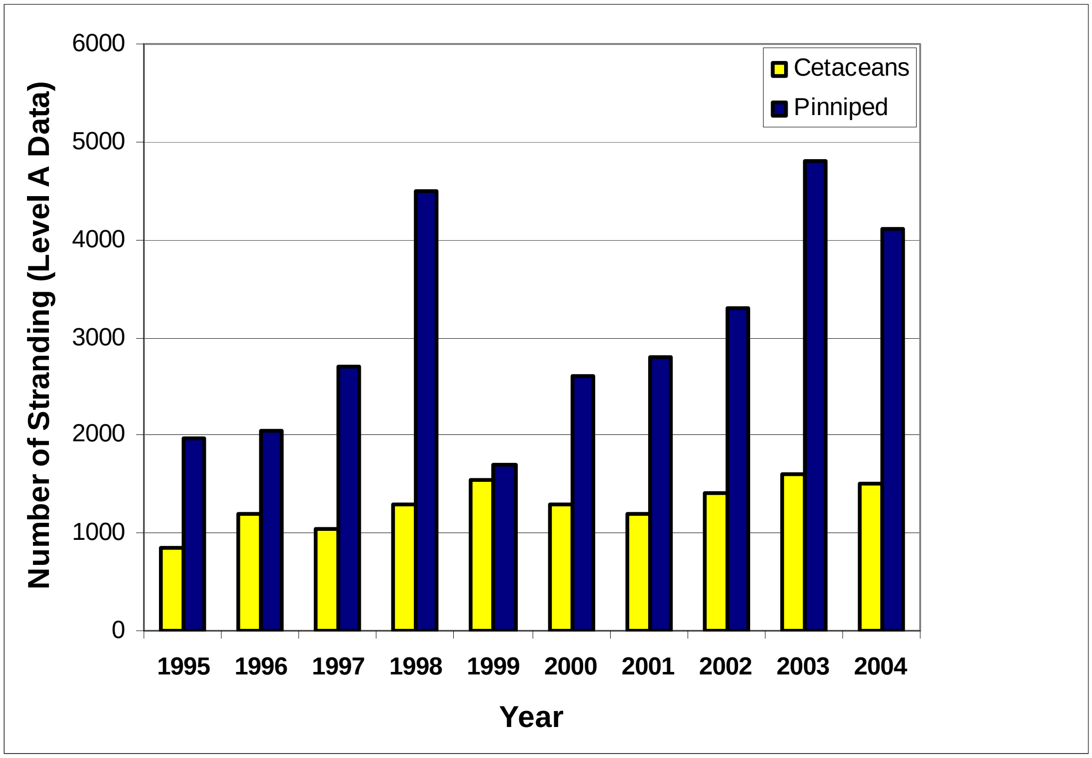


Figure D-1. United States Annual Cetacean and Pinniped Stranding Events from 1995-2004
(Source: NMFS 2007)

D.2 POTENTIAL CAUSES OF MARINE MAMMAL STRANDING

Reports of marine mammal strandings can be traced back to ancient Greece (Walsh et al., 2001). Like any wildlife population, there are normal background mortality rates that influence marine mammal population dynamics, including starvation, predation, aging, reproductive success, and disease (Geraci et al., 1999; Carretta et al., 2007). Strandings in and of themselves may be reflective of this natural cycle or, more recently, may be the result of anthropogenic sources (i.e., human impacts). Current science suggests that multiple factors, both natural and man-made, may be acting alone or in combination to cause a marine mammal to strand (Geraci et al., 1999; Culik, 2002; Perrin and Geraci, 2002; Hoelzel, 2003; Geraci and Lounsbury, 2005; NRC, 2006). While post-stranding data collection and necropsies of dead animals are attempted in an effort to find a possible cause for the stranding, it is often difficult to pinpoint exactly one factor that can be blamed for any given stranding. An animal suffering from one ailment becomes susceptible to various other influences because of its weakened condition, making it difficult to determine a primary cause. In many stranding cases, scientists never learn the exact reason for the stranding.
Specific potential stranding causes can include both natural and human influenced (anthropogenic) causes listed below and described in the following sections:

Natural Stranding Causes

- Disease
- Natural toxins
- Weather and climatic influences

- Navigation errors
- Social cohesion
- Predation

Human Influenced (Anthropogenic) Stranding Causes

- Fisheries interaction
- Vessel strike
- Pollution and ingestion
- Noise

D.3 CAUSES OF NATURAL STRANDING

Overview

Significant natural causes of mortality, die-offs, and stranding discussed below include disease and parasitism; marine neurotoxins from algae; navigation errors that lead to inadvertent stranding; and climatic influences that impact the distribution and abundance of potential food resources (i.e., starvation). Other natural mortality not discussed in detail includes predation by other species such as sharks (Cockcroft et al., 1989; Heithaus, 2001), killer whales (Constantine et al., 1998; Guinet et al., 2000; Pitman et al., 2001), and some species of pinniped (Hiruki et al., 1999; Robinson et al., 1999).

Disease

Like other mammals, marine mammals frequently suffer from a variety of diseases of viral, bacterial, and fungal origin (Visser et al., 1991; Dunn et al., 2001; Harwood, 2002). Gulland and Hall (2005, 2007) provide a more detailed summary of individual and population effects of marine mammal diseases.

Microparasites such as bacteria, viruses, and other microorganisms are commonly found in marine mammal habitats and usually pose little threat to a healthy animal (Geraci et al., 1999). For example, long-finned pilot whales that inhabit the waters off of the northeastern coast of the U.S. are carriers of the morbillivirus, yet have grown resistant to its usually lethal effects (Geraci et al., 1999). Since the 1980s, however, virus infections have been strongly associated with marine mammal die-offs (Domingo et al., 1992; Geraci and Lounsbury, 2005). Morbillivirus is the most significant marine mammal virus and suppresses a host's immune system, increasing risk of secondary infection (Harwood, 2002). A bottlenose dolphin UME in 1993 and 1994 was caused by morbillivirus. Die-offs ranged from northwestern Florida to Texas, with an increased number of deaths as it spread (NMFS, 2007). A 2004 UME in Florida was also associated with dolphin morbillivirus (NMFS, 2004). Influenza A was responsible for the first reported mass mortality in the U.S., occurring along the coast of New England in 1979-1980 (Geraci et al., 1999; Harwood, 2002). Canine distemper virus has been responsible for large scale pinniped mortalities and die-offs (Grachev et al., 1989; Kennedy et al., 2000; Gulland and Hall, 2005), while a bacteria, *Leptospira pomona*, is responsible for periodic die-offs in California sea lions about every four years (Gulland et al., 1996; Gulland and Hall, 2005). It is difficult to determine whether microparasites commonly act as a primary pathogen, or whether they show up as a secondary infection in an already weakened animal (Geraci et al., 1999). Most marine mammal die-offs from infectious disease in the last 25 years, however, have had viruses associated with them (Simmonds and Mayer, 1997; Geraci et al., 1999; Harwood, 2002).

Macroparasites are usually large parasitic organisms and include lungworms, trematodes (parasitic flatworms), and protozoans (Geraci and St.Aubin, 1987; Geraci et al., 1999). Marine mammals can carry many different types, and have shown a robust tolerance for sizeable infestation unless compromised by illness, injury, or starvation (Morimitsu et al., 1987; Dailey et al., 1991; Geraci et al., 1999). Nasitrema, a usually benign trematode found in the head sinuses of cetaceans (Geraci et al., 1999), can cause brain damage if it migrates (Ridgway and Dailey, 1972). As a result, this worm is one of the few directly linked to stranding in the cetaceans (Dailey and Walker, 1978; Geraci et al., 1999).

Non-infectious disease, such as congenital bone pathology of the vertebral column (osteomyelitis, spondylosis deformans, and ankylosing spondylitis [AS]), has been described in several species of cetacean (Paterson, 1984; Alexander et al., 1989; Kompanje, 1995; Sweeny et al., 2005). In humans, bone pathology such as AS, can impair mobility and increase vulnerability to further spinal trauma (Resnick and Niwayama, 2002). Bone pathology has been found in cases of single strandings (Paterson, 1984; Kompanje, 1995), and also in cetaceans prone to mass stranding (Sweeny et al., 2005), possibly acting as a contributing or causal influence in both types of events.

Naturally Occurring Marine Neurotoxins

Some single cell marine algae common in coastal waters, such as dinoflagellates and diatoms, produce toxic compounds that can accumulate (termed bioaccumulation) in the flesh and organs of fish and invertebrates (Geraci et al., 1999; Harwood, 2002). Marine mammals become exposed to these compounds when they eat prey contaminated by these naturally produced toxins (Van Dolah, 2005). Figure 2 shows U.S. animal mortalities from 1997-2006 resulting from toxins produced during harmful algal blooms.

In the Gulf of Mexico and mid- to southern Atlantic states, "red tides," a form of harmful algal bloom, are created by a dinoflagellate (*Karenia brevis*). *K. brevis* is found throughout the Gulf of Mexico and sometimes along the Atlantic coast (Van Dolah, 2005; NMFS, 2007). It produces a neurotoxin known as brevetoxin. Brevetoxin has been associated with several marine mammal UMEs within this area (Geraci, 1989; Van Dolah et al., 2003; NMFS, 2004; Flewelling et al., 2005; Van Dolah, 2005; NMFS, 2007). On the U.S. west coast and in the northeast Atlantic, several species of diatoms produce a toxin called domoic acid which has also been linked to marine mammal strandings (Geraci et al., 1999; Van Dolah et al., 2003; Greig et al., 2005; Van Dolah, 2005; Brodie et al., 2006; NMFS, 2007). Other algal toxins associated with marine mammal strandings include saxitoxins and ciguatoxins and are summarized by Van Dolah (2005).

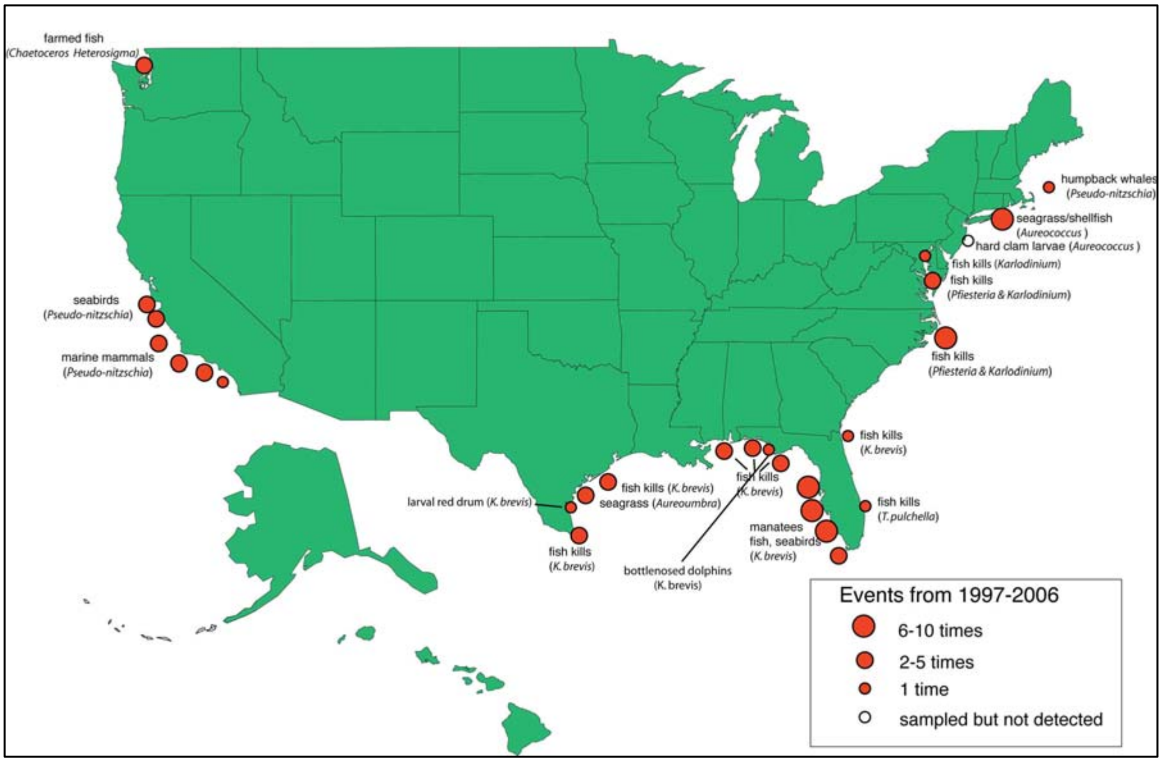


Figure D-2. Animal Mortalities from Harmful Algal Blooms within the U.S. from 1997-2006

Source: Woods Hole Oceanographic Institute (WHO) http://www.whoi.edu/redtide/HABdistribution/HABmap.html

Table D-1. Marine Mammal Unusual Mortality Events Attributed to or Suspected from Natural Causes 1978-2005

Year	Species and number	Location	Cause
1978	Hawaiian monk seals (50)	NW Hawaiian Islands	Ciguatoxin and maitotoxin
1979-80	Harbor seals (400)	Massachusetts	Influence A
1982	Harbor seals	Massachusetts	Influence A
1983	Multiple pinniped species	West coast of U.S., Galapagos	El Nino
1984	California sea lions (226)	California	Leptospirosis
1987	Sea otters (34)	Alaska	Saxitoxin
1987	Humpback whales (14)	Massachusetts	Saxitoxin
1987-88	Bottlenose dolphins (645)	Eastern seaboard (New Jersey to Florida)	Morbillivirus; Brevetoxin
1987-88	Baikal seals (80-100,000)	Lake Baikal, Russia	Canine distemper virus
1988	Harbor seals (approx 18,000)	Northern Europe	Phocine distemper virus
1990	Stripped dolphins (550)	Mediterranean Sea	Dolphin morbillivirus
1990	Bottlenose dolphins (146)	Gulf Coast, U.S.	Unknown; unusual skin lesions observed
1994	Bottlenose dolphins (72)	Texas	Morbillivirus
1995	California sea lions (222)	California	Leptospirosis
1996	Florida manatees (149)	West Coast Florida	Brevetoxin
1996	Bottlenose dolphins (30)	Mississippi	Unknown; Coincident with algal bloom
1997	Mediterranean monk seals (150)	Western Sahara, Africa	Harmful algal bloom; Morbillivirus
1997-98	California sea lions (100s)	California	El Nino
1998	California sea lions (70)	California	Domoic acid

Table D-1. Marine Mammal Unusual Mortality Events Attributed to or Suspected from Natural Causes 1978-2005 Cont'd

Year	Species and number	Location	Cause
1998	Hooker's sea lions (60% of pups)	New Zealand	Unknown, bacteria likely
1999	Harbor porpoises	Maine to North Carolina	Oceanographic factors suggested
2000	Caspian seals (10,000)	Caspian Sea	Canine distemper virus
1999-2000	Bottlenose dolphins (115)	Panhandle of Florida	Brevetoxin
1999-2001	Gray whales (651)	Canada, U.S. West Coast, Mexico	Unknown; starvation involved
2000	California sea lions (178)	California	Leptospirosis
2000	California sea lions (184)	California	Domoic acid
2000	Harbor seals (26)	California	Unknown; Viral pneumonia suspected
2001	Bottlenose dolphins (35)	Florida	Unknown
2001	Harp seals (453)	Maine to Massachusetts	Unknown
2001	Hawaiian monk seals (11)	NW Hawaiian Islands	Malnutrition
2002	Harbor seals (approx. 25,000)	Northern Europe	Phocine distemper virus
2002	Multispecies (common dolphins, California sea lions, sea otters) (approx. 500)	California	Domoic acid
2002	Hooker's sea lions	New Zealand	Pneumonia
2002	Florida manatee	West Coast of Florida	Brevetoxin
2003	Multispecies (common dolphins, California sea lions, sea otters) (approx. 500)	California	Domoic acid
2003	Beluga whales (20)	Alaska	Ecological factors
2003	Sea otters	California	Ecological factors
2003	Large whales (16 humpback, 1 fine, 1 minke, 1 pilot, 2 unknown)	Maine	Unknown; Saxitoxin and domoic acid detected in 2 of 3 humpbacks
2003-2004	Harbor seals, minke whales	Gulf of Maine	Unknown
2003	Florida manatees (96)	West Coast of Florida	Brevetoxin
2004	Bottlenose dolphins (107)	Florida Panhandle	Brevetoxin
2004	Small cetaceans (67)	Virginia	Unknown
2004	Small cetaceans	North Carolina	Unknown
2004	California sea lions (405)	Canada, U.S. West Coast	Leptospirosis
2005	Florida manatees, bottlenose dolphins (ongoing Dec 2005)	West Coast of Florida	Brevetoxin
2005	Harbor porpoises	North Carolina	Unknown
2005	California sea lions; Northern fur seals	California	Domoic acid
2005	Large whales	Eastern North Atlantic	Domoic acid suspected
2005-2006	Bottlenose dolphins	Florida	Brevetoxin suspected
Note: Data from Gulland and Hall (2007); citations for each event contained in Gulland and Hall (2007)			

Weather Events and Climate Influences

Severe storms, hurricanes, typhoons, and prolonged temperature extremes may lead to localized marine mammal strandings (Geraci et al., 1999; Walsh et al., 2001). Hurricanes may have been responsible for mass strandings of pygmy killer whales in the British Virgin Islands and Gervais' beaked whales in North Carolina (Mignucci-Giannoni et al., 2000; Norman and Mead, 2001). Storms in 1982-1983 along the California coast led to deaths of 2,000 northern elephant seal pups (Le Boeuf and Reiter, 1991). Ice movement along southern Newfoundland has forced groups of blue whales and white-beaked dolphins ashore (Sergeant, 1982). Seasonal oceanographic conditions in terms of weather, frontal systems, and local currents may also play a role in stranding (Walker et al., 2005).

The effect of large scale climatic changes to the world's oceans and how these changes impact marine mammals and influence strandings is difficult to quantify given the broad spatial and temporal scales involved, and the cryptic movement patterns of marine mammals (Moore, 2005; Learmonth et al., 2006). The most immediate, although indirect, effect is decreased prey availability during unusual conditions. This, in turn, results in increased search effort required by marine mammals (Crocker et al., 2006), potential starvation if not successful, and corresponding stranding due directly to starvation or succumbing to disease or predation while in a more weakened, stressed state (Selzer and Payne, 1988; Geraci et al., 1999; Moore, 2005; Learmonth et al., 2006; Weise et al., 2006).

Two recent papers examined potential influences of climate fluctuation on stranding events in southern Australia, including Tasmania, an area with a history of more than 20 mass stranding since the 1920s (Evans et al., 2005; Bradshaw et al., 2006). These authors note that patterns in animal migration, survival, fecundity, population size, and strandings will revolve around the availability and distribution of food resources. In southern Australia, movement of nutrient-rich waters pushed closer to shore by periodic meridinal winds (occurring about every 12 – 14 years) may be responsible for bringing marine mammals closer to land, thus increasing the probability of stranding (Bradshaw et al., 2006). The papers conclude, however, that while an overarching model can be helpful for providing insight into the prediction of strandings, the particular reasons for each one are likely to be quite varied.

Navigational Error

Geomagnetism- It has been hypothesized that, like some land animals, marine mammals may be able to orient to the Earth's magnetic field as a navigational cue, and that areas of local magnetic anomalies may influence strandings (Bauer et al., 1985; Klinowska, 1985; Kirschvink et al., 1986; Klinowska, 1986; Walker et al., 1992; Wartzok and Ketten, 1999). In a plot of live stranding positions in Great Britain with magnetic field maps, Klinowska (1985, 1986) observed an association between live stranding positions and magnetic field levels. In all cases, live strandings occurred at locations where magnetic minima, or lows in the magnetic fields, intersect the coastline. Kirschvink et al. (1986) plotted stranding locations on a map of magnetic data for the east coast of the U.S., and were able to develop associations between stranding sites and locations where magnetic minima intersected the coast. The authors concluded that there were highly significant tendencies for cetaceans to beach themselves near these magnetic minima and coastal intersections. The results supported the hypothesis that cetaceans may have a magnetic sensory system similar to other migratory animals, and that marine magnetic topography and patterns may influence long-distance movements (Kirschvink et al., 1986). Walker et al. (1992) examined fin whale swim patterns off the northeastern U.S. continental shelf, and reported that migrating animals aligned with lows in the geometric gradient or intensity. While a similar pattern between magnetic features and marine mammal strandings at New Zealand stranding sites was not seen (Brabyn and Frew, 1994), mass strandings in Hawaii typically were found to occur within a narrow range of magnetic anomalies (Mazzuca et al., 1999).

Echolocation Disruption in Shallow Water- Some researchers believe stranding may result from reductions in the effectiveness of echolocation within shallow water, especially with the pelagic species of odontocetes who may be less familiar with coastline (Dudok van Heel, 1966; Chambers and James, 2005). For an odontocete, echoes from echolocation signals contain important information on the location and identity of underwater objects and the shoreline. The authors postulate that the gradual slope of a beach may present difficulties to the navigational systems of some cetaceans, since it is common for live strandings to occur along beaches with shallow, sandy gradients (Brabyn and McLean, 1992; Mazzuca et al., 1999; Maldini et al., 2005; Walker et al., 2005). A contributing factor to echolocation interference in turbulent, shallow water is the presence of microbubbles from the interaction of wind, breaking waves, and currents. Additionally, ocean water near the shoreline can have an increased turbidity (e.g., floating sand or silt, particulate plant matter, etc.) due to the run-off of fresh water into the ocean, either from rainfall or from freshwater outflows (e.g., rivers and creeks). Collectively, these factors can reduce and scatter the sound energy within echolocation signals and reduce the perceptibility of returning echoes of interest.

Social Cohesion

Many pelagic species such as sperm whale, pilot whales, melon-head whales, and false killer whales, and some dolphins occur in large groups with strong social bonds between individuals. When one or more animals strand due to any number of causative events, then the entire pod may follow suit out of social cohesion (Geraci et al., 1999; Conner, 2000; Perrin and Geraci, 2002; NMFS, 2007).

D.4 ANTHROPOGENIC CAUSES OF STRANDING

Overview

With the exception of historic whaling in the 19th and early part of the 20th century, during the past few decades there has been an increase in marine mammal mortalities associated with a variety of human activities (Geraci et al., 1999; NMFS, 2007). These include fisheries interactions (bycatch and directed catch), pollution (marine debris, toxic compounds), habitat modification (degradation, prey reduction), vessel strikes (Laist et al., 2001), and gunshots. Figure 3 shows potential worldwide risk to small-toothed cetaceans by source.

Fisheries Interactions

The incidental catch of marine mammals in commercial fisheries is a significant threat to the survival and recovery of many populations of marine mammals (Geraci et al., 1999; Baird, 2002; Culik, 2002; Carretta et al., 2004; Geraci and Lounsbury, 2005; NMFS, 2007). Interactions with fisheries and entanglement in discarded or lost gear continue to be a major factor in marine mammal deaths worldwide (Geraci et al., 1999; Nieri et al., 1999; Geraci and Lounsbury, 2005; Read et al., 2006; Zeeber et al., 2006). For instance, baleen whales and pinnipeds have been found entangled in nets, ropes, monofilament line, and other fishing gear that has been discarded out at sea (Geraci et al., 1999; Campagna et al., 2007).

Bycatch- Bycatch is the catching of non-target species within a given fishing operation and can include non-commercially used invertebrates, fish, sea turtles, birds, and marine mammals (NRC, 2006). Read et al. (2006) attempted to estimate the magnitude of marine mammal bycatch in U.S. and global fisheries. Data on marine mammal bycatch within the United States was obtained from fisheries observer programs, reports of entangled stranded animals, and fishery logbooks, and was then extrapolated to estimate global bycatch by using the ratio of U.S. fishing vessels to the total number of vessels within the world's fleet (Read et al., 2006). Within U.S. fisheries, between 1990 and 1999 the mean annual bycatch of marine mammals was 6,215 animals, with a standard error of +/- 448 (Read et al., 2006). Eight-four percent of cetacean bycatch occurred in gill-net fisheries, with dolphins and porpoises constituting most of the cetacean bycatch (Read et al., 2006). Over the decade there was a 40 percent decline in marine mammal bycatch, which was significantly lower from 1995-1999 than it was from 1990-1994 (Read et al., 2006). Read et al. (2006) suggests that this is primarily due to effective conservation measures that were implemented during this time period.

Read et al. (2006) then extrapolated this data for the same time period and calculated an annual estimate of 653,365 of marine mammals globally, with most of the world's bycatch occurring in gill-net fisheries. With global marine mammal bycatch likely to be in the hundreds of thousands every year, bycatch in fisheries will be the single greatest threat to many marine mammal populations around the world (Read et al., 2006).

Entanglement- Entanglement in active fishing gear is a major cause of death or severe injury among the endangered whales in the action area. Entangled marine mammals may die as a result of drowning, escape with pieces of gear still attached to their bodies, or manage to be set free either of their own accord or by fishermen. Many large whales carry off gear after becoming entangled (Read et al., 2006). Many times when a marine mammal swims off with gear attached, the end result can be fatal. The gear may be become too cumbersome for the animal, or it can be wrapped around a crucial body part and tighten over time. Stranded marine mammals frequently exhibit signs of previous fishery interaction, such as scarring or gear attached to their bodies, and the cause of death for many stranded marine mammals is often attributed to such interactions (Baird and Gorgone, 2005). Because marine mammals that die or are injured in fisheries may not wash ashore and not all animals that do wash ashore exhibit clear signs of interactions, stranding data probably underestimate fishery-related mortality and serious injury (NMFS, 2005a).

From 1993 through 2003, 1,105 harbor porpoises were reported stranded from Maine to North Carolina, many of which had cuts and body damage suggestive of net entanglement (NMFS, 2005d). In 1999 it was possible to determine that the cause of death for 38 of the stranded porpoises was from fishery interactions, with one additional animal having been mutilated (right flipper and fluke cut off) (NMFS, 2005d). In 2000, one stranded porpoise was found with monofilament line wrapped around its body (NMFS, 2005d). And in 2003, nine stranded harbor porpoises were attributed to fishery interactions, with an additional three mutilated animals (NMFS, 2005d). An estimated 78 baleen whales were killed annually in the offshore southern California/Oregon drift gillnet fishery during the 1980s (Heyning and Lewis 1990).

Ship Strike

Vessel strikes to marine mammals are another cause of mortality and stranding (Laist et al. 2001; Geraci and Lounsbury, 2005; de Stephanis and Urquiola, 2006). An animal at the surface could be struck directly by a vessel, a surfacing animal could hit the bottom of a vessel, or an animal just below the surface could be cut by a vessel's propeller. The severity of injuries typically depends on the size and speed of the vessel (Knowlton and Kraus, 2001; Laist et al., 2001; Vanderlaan and Taggart 2007).

An examination of all known ship strikes from all shipping sources (civilian and military) indicates vessel speed is a principal factor in whether a vessel strike results in death (Knowlton and Kraus 2001; Laist et al. 2001, Jensen and Silber 2003; Vanderlaan and Taggart 2007). Jensen and Silber (2003) detailed 292 records of known or probable ship strikes of all large whale species from 1975 to 2002. Of these, vessel speed at the time of collision was reported for 58 cases. Of these cases, 39 (or 67%) resulted in serious injury or death (19 or 33% resulted in serious injury as determined by blood in the water, propeller gashes or severed tailstock, and fractured skull, jaw, vertebrae, hemorrhaging, massive bruising or other injuries noted during necropsy and 20 or 35% resulted in death). Operating speeds of vessels that struck various species of large whales ranged from 2 to 51 knots. The majority (79%) of these strikes occurred at speeds of 13 knots or greater. The average speed that resulted in serious injury or death was 18.6 knots. Pace and Silber (2005) found that the probability of death or serious injury increased rapidly with increasing vessel speed. Specifically, the predicted probability of serious injury or death increased from 45 percent to 75 % as vessel speed increased from 10 to 14 knots, and exceeded 90% at 17 knots. Higher speeds during collisions result in greater force of impact, but higher speeds also appear to increase the chance of severe injuries or death by pulling whales toward the vessel. Computer simulation modeling showed that hydrodynamic forces pulling whales toward the vessel hull increase with increasing speed (Clyne 1999, Knowlton et al. 1995).

The growth in civilian commercial ports and associated commercial vessel traffic is a result in the globalization of trade. The Final Report of the NOAA International Symposium on "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology" stated that the worldwide commercial fleet has grown from approximately 30,000 vessels in 1950 to over 85,000 vessels in 1998 (NRC, 2003; Southall, 2005). Between 1950 and 1998, the U.S. flagged fleet declined from approximately 25,000 to less than 15,000 and currently represents only a small portion of the world fleet. From 1985 to 1999, world seaborne trade doubled to 5 billion tons and currently includes 90 percent of the total world trade, with container shipping movements representing the largest volume of seaborne trade. It is unknown how international shipping volumes and densities will continue to grow. However, current statistics support the prediction that the international shipping fleet will continue to grow at the current rate or at greater rates in the future. Shipping densities in specific areas and trends in routing and vessel design are as, or more, significant than the total number of vessels. Densities along existing coastal routes are expected to increase both domestically and internationally. New routes are also expected to develop as new ports are opened and existing ports are expanded. Vessel propulsion systems are also advancing toward faster ships operating in higher sea states for lower operating costs; and container ships are expected to become larger along certain routes (Southall, 2005).

While there are reports and statistics of whales struck by vessels in U.S. waters, the magnitude of the risks of commercial ship traffic poses to marine mammal populations is difficult to quantify or estimate. In addition, there is limited information on vessel strike interactions between ships and marine mammals outside of U.S. waters (de Stephanis and Urquiola, 2006). Laist et al. (2001) concluded that ship collisions may have a negligible effect on most marine mammal populations in general, except for regional based small populations where the significance of low numbers of collisions would be greater given smaller populations or populations segments.

The U.S. Department of Navy (DON) vessel traffic is a small fraction of the overall U.S. commercial and fishing vessel traffic. While DON vessel movements may contribute to the ship strike threat, given the lookout and mitigation measures adopted by the DON, probability of vessel strikes is greatly reduced. Furthermore, actions to avoid close interaction of DON ships and marine mammals and sea turtles, such as maneuvering to keep away from any observed marine mammal and sea turtle are part of existing at-sea protocols and standard operating procedures. Navy ships have up to three or more dedicated and trained lookouts as well as two to three bridge watchstanders during at-sea movements who would be searching for any whales, sea turtles, or other obstacles on the water surface. Such lookouts are expected to further reduce the chances of a collision.

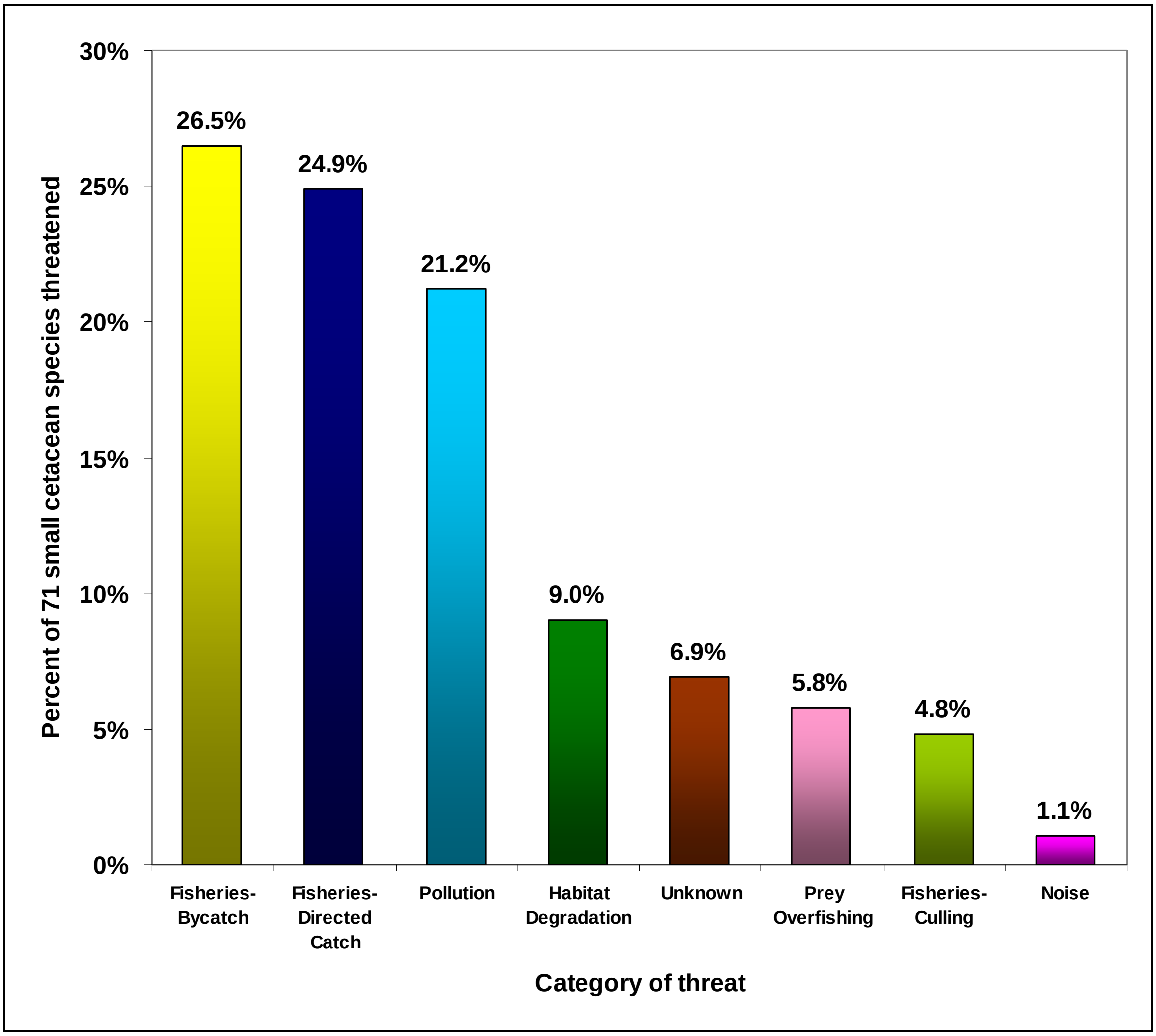


Figure D-3. Human Threats to Worldwide Small Cetacean Populations*
(Source: Culik 2002)
*The Navy realizes that the total percentages add up to 100.2 percent;
however this figure is referenced directly from the aforementioned report.

Ingestion of Plastic Objects and Other Marine Debris And Toxic Pollution Exposure

For many marine mammals, debris in the marine environment is a great hazard and can be harmful to wildlife. Not only is debris a hazard because of possible entanglement, animals may mistake plastics and other debris for food (NMFS, 2007b). There are certain species of cetaceans, along with Florida manatees, that are more likely to eat trash, especially plastics, which is usually fatal for the animal (Geraci et al., 1999).

Between 1990 through October 1998, 215 pygmy sperm whales stranded along the U.S. Atlantic coast from New York through the Florida Keys (NMFS, 2005a). Remains of plastic bags and other debris were found in the stomachs of 13 of these animals (NMFS, 2005a). During the same time period, 46 dwarf sperm whale strandings occurred along the U.S. Atlantic coastline between Massachusetts and the Florida Keys (NMFS, 2005c). In 1987 a pair of latex examination gloves was retrieved from the stomach of a stranded dwarf sperm whale (NMFS, 2005c). 125 pygmy sperm whales were reported stranded from 1999 – 2003 between Maine and Puerto Rico; in one pygmy sperm whale found stranded in 2002, red plastic debris was found in the stomach along with squid beaks (NMFS, 2005a).

Sperm whales have been known to ingest plastic debris, such as plastic bags (Evans and Hindell, 2004; Whitehead 2003). While this has led to mortality, the scale to which this is affecting sperm whale populations is unknown, but Whitehead (2003) suspects it is not substantial at this time.
High concentrations of potentially toxic substances within marine mammals along with an increase in new diseases have been documented in recent years. Scientists have begun to consider the possibility of a link between pollutants and marine mammal mortality events. NMFS takes part in a marine mammal bio-monitoring program not only to help assess the health and contaminant loads of marine mammals, but also to assist in determining anthropogenic impacts on marine mammals, marine food chains and marine ecosystem health. Using strandings and bycatch animals, the program provides tissue/serum archiving, samples for analyses, disease monitoring and reporting, and additional response during disease investigations (NMFS, 2007).
The impacts of these activities are difficult to measure. However, some researchers have correlated contaminant exposure to possible adverse health effects in marine mammals. Contaminants such as organochlorines do not tend to accumulate in significant amounts in invertebrates, but do accumulate in fish and fish-eating animals. Thus, contaminant levels in planktivorous mysticetes have been reported to be one to two orders of magnitude lower compared to piscivorous odontocetes (Borell 1993; O'Shea and Brownell 1994; O'Hara and Rice 1996; O'Hara et al. 1999).

The manmade chemical PCB (polychlorinated biphenyl), and the pesticide DDT ((dichlorodiphyenyltrichloroethane), are both considered persistent organic pollutants that are currently banned in the United States for their harmful effects in wildlife and humans (NMFS, 2007a). Despite having been banned for decades, the levels of these compounds are still high in marine mammal tissue samples taken along U.S. coasts (NMFS, 2007a). Both compounds are long-lasting, reside in marine mammal fat tissues (especially in the blubber), and can be toxic causing effects such as reproductive impairment and immunosuppression (NMFS, 2007a).

Both long-finned and short-finned pilot whales have a tendency to mass strand throughout their range. Short-finned pilot whales have been reported as stranded as far north as Rhode Island, and long-finned pilot whales as far south as South Carolina (NMFS, 2005b). For U.S. east coast stranding records, both species are lumped together and there is rarely a distinction between the two because of uncertainty in species identification (NMFS, 2005b). Since 1980 within the Northeast region alone, between 2 and 120 pilot whales have stranded annually either individually or in groups (NMFS, 2005b). Between 1999 and 2003 from Maine to Florida, 126 pilot whales were reported to be stranded, including a mass stranding of 11 animals in 2000 and another mass stranding of 57 animals in 2002, both along the Massachusetts coast (NMFS, 2005b).

It is unclear how much of a role human activities play in these pilot whale strandings, and toxic poisoning may be a potential human-caused source of mortality for pilot whales (NMFS, 2005b). Moderate levels of PCBs and chlorinated pesticides (such as DDT, DDE, and dieldrin) have been found in pilot whale blubber (NMFS, 2005b). Bioaccumulation levels have been found to be more similar in whales from the same stranding event than from animals of the same age or sex (NMFS, 2005b). Numerous studies have measured high levels of toxic metals (mercury, lead, and cadmium), selenium, and PCBs in pilot whales in the Faroe Islands (NMFS, 2005b).

Population effects resulting from such high contamination levels are currently unknown (NMFS, 2005b).

Habitat contamination and degradation may also play a role in marine mammal mortality and strandings. Some events caused by man have direct and obvious effects on marine mammals, such as oil spills (Geraci et al., 1999). But in most cases, effects of contamination will more than likely be indirect in nature, such as effects on prey species availability, or by increasing disease susceptibility (Geraci et al., 1999).

DON vessel operation between ports and exercise locations has the potential for release of small amounts of pollutant discharges into the water column. DON vessels are not a typical source, however, of either pathogens or other contaminants with bioaccumulation potential such as pesticides and PCBs. Furthermore, any vessel discharges such as bilgewater and deck runoff associated with the vessels would be in accordance with international and U.S. requirements for eliminating or minimizing discharges of oil, garbage, and other substances, and not likely to contribute significant changes to ocean water quality.

Anthropogenic Sound

As one of the potential stressors to marine mammal populations, noise and acoustic influences may disrupt marine mammal communication, navigational ability, and social patterns, and may or may not influence stranding. Many marine mammals use sound to communicate, navigate, locate prey, and sense their environment. Both anthropogenic and natural sounds may cause interference with these functions, although comprehension of the type and magnitude of any behavioral or physiological responses resulting from man-made sound, and how these responses may contribute to strandings, is rudimentary at best (NMFS, 2007). Marine mammals may respond both behaviorally and physiologically to anthropogenic sound exposure, (e.g., Richardson et al., 1995; Finneran et al., 2000; Finneran et al., 2003; Finneran et al., 2005, NRC, 2005); however, the range and magnitude of the behavioral response of marine mammals to various sound sources is highly variable (Richardson et al., 1995; NRC 2005) and appears to depend on the species involved, the experience of the animal with the sound source, the motivation of the animal (e.g., feeding, mating), and the context of the exposure.

The marine mammals are regularly exposed to several sources of natural and anthropogenic sounds. Anthropogenic noise that could affect ambient noise arise from the following general types of activities in and near the sea, any combination of which, can contribute to the total noise at any one place and time. These noises include: transportation; dredging; construction; oil, gas, and mineral exploration in offshore areas; geophysical (seismic) surveys; sonar; explosions; and ocean research activities (Richardson et al., 1995). Commercial fishing vessels, cruise ships, transport boats, recreational boats, and aircraft, all contribute sound into the ocean (NRC, 2003; NRC, 2006). Several investigators have argued that anthropogenic sources of noise have increased ambient noise levels in the ocean over the last 50 years (NRC 1994, 1996, 2000, 2003, 2005; Richardson et al., 1995; Jasny et al., 2005; McDonald et al., 2006). Much of this increase is due to increased shipping due to ships becoming more numerous and of larger tonnage (NRC, 2003; McDonald et al., 2006). Andrew et al. (2002) compared ocean ambient sound from the 1960s with the 1990s for a receiver off the California coast. The data showed an increase in ambient noise of approximately 10 dB in the frequency range of 20 to 80 Hz and 200 and 300 Hz, and about 3 dB at 100 Hz over a 33-year period.

Urick (1983) provided a discussion of the ambient noise spectrum expected in the deep ocean. Shipping, seismic activity, and weather, are the primary causes of deep-water ambient noise. The ambient noise frequency spectrum can be predicted fairly accurately for most deep-water areas based primarily on known shipping traffic density and wind state (wind speed, Beaufort wind force, or sea state) (Urick, 1983). For example, for frequencies between 100 and 500 Hz, Urick (1983) estimated the average deep water ambient noise spectra to be 73 to 80 dB for areas of heavy shipping traffic and high sea states, and 46 to 58 dB for light shipping and calm seas. In contrast to deep water, ambient noise levels in shallow waters (i.e., coastal areas, bays, harbors, etc.) are subject to wide variations in level and frequency depending on time and location. The primary sources of noise include distant shipping and industrial activities, wind and waves, marine animals (Urick, 1983). At any give time and place, the ambient noise is a mixture of all of these noise variables. In addition, sound propagation is also affected by the variable shallow water conditions, including the depth, bottom slope, and type of bottom. Where the bottom is reflective, the sounds levels tend to be higher, then when the bottom is absorptive.

Most observations of behavioral responses of marine mammals to the sounds produced have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions. Carretta et al. (2001) and Jasny et al. (2005) identified increasing levels of anthropogenic noise as a habitat concern for whales and other marine mammals because of its potential effect in their ability to communicate. Acoustic devices have also been used in fisheries nets to prevent marine mammal entanglement (Goodson 1997; NMFS 1997; MMC 1999) and to deter seals from salmon cages (Johnson and Woodley 1998), little is known about their effects on non-target species

Noise from Aircraft and Vessel Movement- Surface shipping is the most widespread source of anthropogenic, low frequency (0 to 1,000 Hz) noise in the oceans and may contribute to over 75% of all human sound in the sea (Simmonds and Hutchinson 1996, ICES, 2005b). The Navy estimated that the 60,000 vessels of the world's merchant fleet, annually emit low frequency sound into the world's oceans for the equivalent of 21.9 million days, assuming that 80 percent of the merchant ships are at sea at any one time (U.S. Department of Navy 2001). Ross (1976) has estimated that between 1950 and 1975, shipping had caused a rise in ambient noise levels of 10 dB. He predicted that this would increase by another 5 dB by the beginning of the 21st century. The National Resource Council (1997) estimated that the background ocean noise level at 100 Hz has been increasing by about 1.5 dB per decade since the advent of propeller-driven ships. Michel et al. (2001) suggested an association between long-term exposure to low frequency sounds from shipping and an increased incidence of marine mammal mortalities caused by collisions with ships.

Airborne sound from a low-flying helicopter or airplane may be heard by marine mammals and turtles while at the surface or underwater. Due to the transient nature of sounds from aircraft involved in at-sea operations, such sounds would not likely cause physical effects but have the potential to affect behaviors. Responses by mammals and turtles could include hasty dives or turns, or decreased foraging (Soto et al., 2006). Whales may also slap the water with flukes or flippers, swim away from the aircraft track.

Sound emitted from large vessels, particularly in the course of transit, is the principal source of noise in the ocean today, primarily due to the properties of sound emitted by civilian cargo vessels (Richardson et al., 1995; Arveson and Vendittis, 2000). Ship propulsion and electricity generation engines, engine gearing, compressors, bilge and ballast pumps, as well as hydrodynamic flow surrounding a ship's hull and any hull protrusions contribute to a large vessels' noise emission into the marine environment. Prop-driven vessels also generate noise through cavitation, which accounts much of the noise emitted by a large vessel depending on its travel speed. Military vessels underway or involved in naval operations or exercises, also introduce anthropogenic noise into the marine environment. Noise emitted by large vessels can be characterized as low-frequency, continuous, and tonal. The sound pressure levels at the vessel will vary according to speed, burden, capacity and length (Richardson et al., 1995; Arveson and Vendittis, 2000). Vessels ranging from 135-337 meters (m) (443-1106 feet [ft]) generate peak source sound levels from 169–200 dB between 8 Hz and 430 Hz, although Arveson and Vendittis (2000) documented components of higher frequencies (10–30 kHz) as a function of newer merchant ship engines and faster transit speeds.

Whales have variable responses to vessel presence or approaches, ranging from apparent tolerance to diving away from a vessel. Unfortunately, it is not always possible to determine whether the whales are responding to the vessel itself or the noise generated by the engine and cavitation around the propeller. Apart from some disruption of behavior, an animal may be unable to hear other sounds in the environment due to masking by the noise from the vessel. Any masking of environmental sounds or conspecific sounds is expected to be temporary, as noise dissipates with a vessel transit through an area.

Vessel noise primarily raises concerns for masking of environmental and conspecific cues. However, exposure to vessel noise of sufficient intensity and/or duration can also result in temporary or permanent loss of sensitivity at a given frequency range, referred to as temporary or permanent threshold shifts (TTS or PTS). Threshold shifts are assumed to be possible in marine mammal species as a result of prolonged exposure to large vessel traffic noise due to its intensity, broad geographic range of effectiveness, and constancy.

Collectively, significant cumulative exposure to individuals, groups, or populations can occur if they exhibit site fidelity to a particular area; for example, whales that seasonally travel to a regular area to forage or breed may be more vulnerable to noise from large vessels compared to transiting whales. Any permanent threshold shift in a marine animal's hearing capability, especially at particular frequencies for which it can normally hear best, can impair its ability to perceive threats, including ships. Whales have variable responses to vessel presence or approaches, ranging from apparent tolerance to diving away from a vessel. It is not possible to determine whether the whales are responding to the vessel itself or the noise generated by the engine and cavitation around the propeller. Apart from some disruption of behavior, an animal may be unable to hear other sounds in the environment due to masking by the noise from the vessel.

Most observations of behavioral responses of marine mammals to human generated sounds have been limited to short-term behavioral responses, which included the cessation of feeding, resting, or social interactions. Nowacek et al. (2007) provide a detailed summary of cetacean response to underwater noise.

Given the sound propagation of low frequency sounds, a large vessel in this sound range can be heard 139-463 kilometers away (Ross 1976 in Polefka 2004). DON vessels, however, have incorporated significant underwater ship quieting technology to reduce their acoustic signature (as compared to a similarly-sized vessel) in order to reduce their vulnerability to detection by enemy passive acoustics (Southall, 2005). Therefore, the potential for TTS or PTS from DON vessel and aircraft movement is extremely low given that the exercises and training events are transitory in time, with vessels moving over large area of the ocean. A marine mammal or sea turtle is unlikely to be exposed long enough at high levels for TTS or PTS to occur. Any masking of environmental sounds or conspecific sounds is expected to be temporary, as noise dissipates with a DON vessel transiting through an area. If behavioral disruptions result from the presence of aircraft or vessels, it is expected to be temporary. Animals are expected to resume their migration, feeding, or other behaviors without any threat to their survival or reproduction. However, if an animal is aware of a vessel and dives or swims away, it may successfully avoid being struck.

Navy Sonar- Naval sonars are designed for three primary functions: submarine hunting, mine hunting, and shipping surveillance. There are two classes of sonars employed by the DON: active sonars and passive sonars. Most active military sonars operate in a limited number of areas, and are most likely not a significant contributor to a comprehensive global ocean noise budget (ICES 2005b).

The effects of mid-frequency active naval sonar on marine wildlife have not been studied as extensively as the effects of air-guns used in seismic surveys (Madsen et al., 2006; Stone and Tasker, 2006; Wilson et al., 2006; Palka and Johnson, 2007; Parente et al., 2007). Maybaum (1989, 1993) observed changes in behavior of humpbacks during playback tapes of the M-1002 system (using 203 dB re 1 µPa-m for study); specifically, a decrease in respiration, submergence, and aerial behavior rates; and an increase in speed of travel and track linearity. Direct comparison of Maybaum's results, however, with U.S Navy mid-frequency active sonar are difficult to make. Maybaum's signal source, the commercial M-1002, is not similar to how naval mid-frequency sonar operates. In addition, behavioral responses were observed during playbacks of a control tape, (i.e. a tape with no sound signal) so interpretation of Maybaum's results are inconclusive.

Research by Nowacek, et al. (2004) on North Atlantic right whales using a whale alerting signal designed to alert whales to human presence suggests that received sound levels of only 133 to 148 pressure level (decibel [dB] re 1 microPascals per meter [µPa-m]) for the duration of the sound exposure may disrupt feeding behavior. The authors did note, however, that within minutes of cessation of the source, a return to normal behavior would be expected. Direct comparison of the Nowacek et al. (2004) sound source to MFA sonar, however, is not possible given the radically different nature of the two sources. Nowacek et al.'s source was a series of non-sonar like sounds designed to purposely alert the whale, lasting several minutes, and covering a broad frequency band. Direct differences between Nowacek et al. (2004) and MFA sonar is summarized below from Nowacek et al. (2004) and Nowacek et al. (2007):

(1) Signal duration: Time difference between the two signals is significant, 18-minute signal used by Nowacek et al. verses < 1-sec for MFA sonar.

(2) Frequency modulation: Nowacek et al. contained three distinct signals containing frequency modulated sounds:

1st - alternating 1-sec pure tone at 500 and 850 Hz

2nd - 2-sec logarithmic down-sweep from 4500 to 500 Hz

3rd - pair of low-high (1500 and 2000 Hz) sine wave tones amplitude modulated at 120 Hz

(3) Signal to noise ratio: Nowacek et al.'s signal maximized signal to noise ratio so that it would be distinct from ambient noise and resist masking.

(4) Signal acoustic characteristics: Nowacek et al.'s signal comprised of disharmonic signals spanning northern right whales' estimated hearing range.

Given these differences, therefore, the exact cause of apparent right whale behavior noted by the authors can not be attributed to any one component since the source was such a mix of signal types.

Stranding Analysis

Over the past two decades, several mass stranding events involving beaked whales have been documented. While beaked whale strandings have occurred since the 1800s (Geraci and Lounsbury, 1993; Cox et al., 2006; Podesta et al., 2006), several mass strandings since have been associated with naval operations that may have included mid-frequency sonar (Simmonds and Lopez-Jurado, 1991; Frantzis, 1998; Jepson et al., 2003; Cox et al., 2006). As Cox et al. (2006) concludes, the state of science can not yet determine if a sound source such as mid-frequency sonar alone causes beaked whale strandings, or if other factors (acoustic, biological, or environmental) must co-occur in conjunction with a sound source.

A review of historical data (mostly anecdotal) maintained by the Marine Mammal Program in the National Museum of Natural History, Smithsonian Institution reports 49 beaked whale mass stranding events between 1838 and 1999. The largest beaked whale mass stranding occurred in the 1870s in New Zealand when 28 Gray's beaked whales (*Mesoplodon grayi*) stranded. Blainsville's beaked whale (*Mesoplodon densirostris*) strandings are rare, and records show that they were involved in one mass stranding in 1989 in the Canary Islands. Cuvier's beaked whales (*Ziphius cavirostris*) are the most frequently reported beaked whale to strand, with at least 19 stranding events from 1804 through 2000 (DoC and DON, 2001; Smithsonian Institution, 2000). By the nature of the data, much of the historic information on strandings over the years is anecdotal, which has been condensed in various reports, and some of the data have been altered or possibly misquoted.

The discussion below centers on those worldwide stranding events that may have some association with naval operations, and global strandings that the DON feels are either inconclusive or can not be associated with naval operations.

Naval Association

In the following sections, specific stranding events that have been assumed to be putatively linked to potential sonar operations are discussed. Of note, these events represent a small overall number of animals over an 11 year period (40 animals) and not all worldwide beaked whale strandings can be linked to naval activity (ICES, 2005a; 2005b; Podesta et al., 2006). Four of the five events occurred during NATO exercises or events where DON presence was limited (Greece, Portugal, Spain). One of the five events involved only DON ships (Bahamas).

Beaked whale stranding events associated with potential naval operations.

1996	May	Greece (NATO/US)
2000	March	Bahamas (US)
2000	May	Portugal, Madeira Islands (NATO/US)
2002	September	Spain, Canary Islands (NATO/US)
2006	January	Spain, Mediterranean Sea coast (NATO/US)

Stranding Events Case Studies

1996 Greece Beaked Whale Mass Stranding (May 12 – 13, 1996)

Description: Twelve Cuvier's beaked whales (*Ziphius cavirostris*) stranded along a 38.2 kilometer (km) (23.7 mile [mi]) stretch of the coast of the Kyparissiakos Gulf on May 12 and 13, 1996 (Frantzis, 1998). From May 11 through May 15, the NATO research vessel Alliance was conducting sonar tests with signals of 600 Hz and 3 kHz and root- mean- squared (rms) sound pressure levels (SPL) of 228 and 226 dB re: 1µPa, respectively (D'Amico and Verboom, 1998; D'Spain et al., 2006). The timing and the location of the testing encompassed the time and location of the whale strandings (Frantzis, 1998).

Findings: Partial necropsies of eight of the animals were performed, including external assessments and the sampling of stomach contents. No abnormalities attributable to acoustic exposure were observed, but the stomach contents indicated that the whales were feeding on cephalods soon before the stranding event. No unusual environmental events before or during the stranding event could be identified (Frantzis, 1998).

Conclusions: The timing and spatial characteristics of this stranding event were atypical of stranding in Cuvier's beaked whale, particularly in this region of the world. No natural phenomenon that might contribute to the stranding event coincided in time with the mass stranding. Because of the rarity of mass strandings in the Greek Ionian Sea, the probability that the sonar tests and stranding coincided in time and location, while being independent of each other, was estimated as being extremely low (Frantzis, 1998). However, because information for the necropsies was incomplete and inconclusive, the cause of the stranding cannot be precisely determined.

2000 Bahamas Marine Mammal Mass Stranding (March 15-16, 2000)

Description: Seventeen marine mammals comprised of Cuvier's beaked whales, Blainville's beaked whales (*Mesoplodon densirostris*), minke whale (*Balaenoptera acutorostrata*), and one spotted dolphin (*Stenella frontalis*), stranded along the Northeast and Northwest Providence Channels of the Bahamas Islands on March 15-16, 2000 (Evans and England, 2001). The strandings occurred over a 36-hour period and coincided with DON use of mid-frequency active sonar within the channel. Navy ships were involved in tactical sonar exercises for approximately 16 hours on March 15. The ships, which operated the AN/SQS-53C and AN/SQS-56, moved through the channel while emitting sonar pings approximately every 24 seconds. The timing of pings was staggered between ships and average source levels of pings varied from a nominal 235 dB SPL (AN/SQS-53C) to 223 dB SPL (AN/SQS-56). The center frequency of pings was 3.3 kHz and 6.8 to 8.2 kHz, respectively.

Seven of the fourteen animals that stranded died on the beach and the other ten animals were returned to the water alive. The animals known to have died included five Cuvier's beaked whales, one Blainville's beaked whale, and the single spotted dolphin. Six necropsies were performed and three of the six necropsied marine mammals (one Cuvier's beaked whale, one Blainville's beaked whale, and the spotted dolphin) were fresh enough to permit identification of pathologies by computerized tomography (CT). Tissues from the remaining three animals were in a state of advanced decomposition at the time of inspection.

Findings: The spotted dolphin demonstrated poor body condition and evidence of a systemic debilitating disease. In addition, since the dolphin stranding site was isolated from the acoustic activities of Navy ships, it was determined that the dolphin stranding was unrelated to the presence of Navy active sonar.

All five necropsied beaked whales were in good body condition and did not show any signs of external trauma or disease. In the two best preserved whale specimens, hemorrhage was associated with the brain and hearing structures. Specifically, subarachnoid hemorrhage within the temporal region of the brain and intracochlear hemorrhages were noted. Similar findings of bloody effusions around the ears of two other moderately decomposed whales were consistent with the same observations in the freshest animals. In addition, three of the whales had small hemorrhages in their acoustic fats, which are fat bodies used in sound production and reception (i.e., fats of the lower jaw and the melon). The best-preserved whale demonstrated acute hemorrhage within the kidney, inflammation of the lung and lymph nodes, and congestion and mild hemorrhage in multiple other organs. Other findings were consistent with stresses and injuries associated with the stranding process. These consisted of external scrapes, pulmonary edema and congestion.

Conclusions: The post-mortem analyses of stranded beaked whales lead to the conclusion that the immediate cause of death resulted from overheating, cardiovascular collapse and stresses associated with being stranded on land. However, the presence of subarachnoid and intracochlear hemorrhages were believed to have occurred prior to stranding and were hypothesized as being related to an acoustic event. Passive acoustic monitoring records demonstrated that no large scale acoustic activity besides the Navy sonar exercise occurred in the times surrounding the stranding event. The mechanism by which sonar could have caused the observed traumas or caused the animals to strand was undetermined. The spotted dolphin was in overall poor condition for examination, but showed indications of long-term disease. No analysis of baleen whales (minke whale) was conducted. Baleen whale stranding events have not been associated with either low-frequency or mid-frequency sonar use (ICES, 2005a, 2005b).

2000 Madeira Island, Portugal Beaked Whale Strandings (May 10 – 14, 2000)

Description: Three Cuvier's beaked whales stranded on two islands in the Madeira Archipelago, Portugal, from May 10 – 14, 2000 (Cox et al., 2006). A joint NATO amphibious training exercise, named "Linked Seas 2000," which involved participants from 17 countries, took place in Portugal during May 2 – 15, 2000. The timing and location of the exercises overlapped with that of the stranding incident.

Findings: Two of the three whales were necropsied. Two heads were taken to be examined. One head was intact and examined grossly and by CT; the other was only grossly examined because it was partially flensed and had been seared from an attempt to dispose of the whale by fire (Ketten, 2005).

No blunt trauma was observed in any of the whales. Consistent with prior CT scans of beaked whales stranded in the Bahamas 2000 incident, one whale demonstrated subarachnoid and peribullar hemorrhage and blood within one of the brain ventricles. Post-cranially, the freshest whale demonstrated renal congestion and hemorrhage, which was also consistent with findings in the freshest specimens in the Bahamas incident.

Conclusions: The pattern of injury to the brain and auditory system were similar to those observed in the Bahamas strandings, as were the kidney lesions and hemorrhage and congestion in the lungs (Ketten, 2005). The similarities in pathology and stranding patterns between these two events suggested a similar causative mechanism. Although the details about whether or how sonar was used during "Linked Seas 2000" is unknown, the presence of naval activity within the region at the time of the strandings suggested a possible relationship to Navy activity.

2002 Canary Islands Beaked Whale Mass Stranding (September 24, 2002)

Description: On September 24, 2002, 14 beaked whales stranded on Fuerteventura and Lanzaote Islands in the Canary Islands (Jepson et al., 2003). Seven of the 14 whales died on the beach and the 7 were returned to the ocean. In addition to these initial strandings, four beaked whales were found stranded dead over the next three days either on the coast or floating offshore (Fernández et al., 2005). At the time of the strandings, an international naval exercise called Neo-Tapon involving numerous surface warships and several submarines was being conducted off the coast of the Canary Islands. Tactical mid-frequency active sonar was utilized during the exercises, and strandings began within hours of the onset of the use of mid-frequency sonar (Fernández et al., 2005).

Findings: Eight Cuvier's beaked whales, one Blainville's beaked whale, and on Gervais' beaked whale were necropsied; six of them within 12 hours of stranding (Fernández et al., 2005). The stomachs of the whales contained fresh and undigested prey contents. No pathogenic bacteria were isolated from the whales, although parasites were found in the kidneys of all of the animals. The head and neck lymph nodes were congested and hemorrhages were noted in multiple tissues and organs, including the kidney, brain, ears, and jaws. Widespread fat emboli were found throughout the carcasses, but no evidence of blunt trauma was observed in the whales. In addition, the parenchyma of several organs contained macroscopic intravascular bubbles and lesions, putatively associated with nitrogen off-gassing.

Conclusions: The association of NATO mid-frequency sonar use close in space and time to the beaked whale strandings, and the similarity between this stranding event and previous beaked whale mass strandings coincident with sonar use, suggests that a similar scenario and causative mechanism of stranding may be shared between the events. Beaked whales stranded in this event demonstrated brain and auditory system injuries, hemorrhages, and congestion in multiple organs, similar to the pathological findings of the Bahamas and Madeira stranding events. In addition, the necropsy results of Canary Islands stranding event lead to the hypothesis that the presence of disseminated and widespread gas bubbles and fat emboli were indicative of nitrogen bubble formation, similar to what might be expected in decompression sickness (Jepson et al., 2003; Fernández et al., 2005). Whereas gas emboli would develop from the nitrogen gas, fat emboli would enter the blood stream from ruptured fat cells (presumably where nitrogen bubble formation occurs) or through the coalescence of lipid bodies within the blood stream.

The possibility that the gas and fat emboli found by Fernández et al. (2005) was due to nitrogen bubble formation has been hypothesized to be related to either direct activation of the bubble by sonar signals or to a behavioral response in which the beaked whales flee to the surface following sonar exposure. The first hypothesis is related to rectified diffusion (Crum and Mao, 1996), the process of increasing the size of a bubble by exposing it to a sound field. This process is facilitated if the environment in which the ensonified bubbles exist is supersaturated with gas. Repetitive diving by marine mammals can cause the blood and some tissues to accumulate gas to a greater degree than is supported by the surrounding environmental pressure (Ridgway and Howard, 1979). Deeper and longer dives of some marine mammals, such as those conducted by beaked whales, are theoretically predicted to induce greater levels of supersaturation (Houser et al., 2001). If rectified diffusion were possible in marine mammals exposed to high-level sound, conditions of tissue supersaturation could theoretically speed the rate and increase the size of bubble growth. Subsequent effects due to tissue trauma and emboli would presumably mirror those observed in humans suffering from decompression sickness. It is unlikely that the short duration of sonar pings would be long enough to drive bubble growth to any substantial size, if such a phenomenon occurs. However, an alternative but related hypothesis has also been suggested: stable bubbles could be destabilized by high-level sound exposures such that bubble growth then occurs through static diffusion of gas out of the tissues. In such a scenario the marine mammal would need to be in a gas-supersaturated state for a long enough period of time for bubbles to become of a problematic size. The second hypothesis speculates that rapid ascent to the surface following exposure to a startling sound might produce tissue gas saturation sufficient for the evolution of nitrogen bubbles (Jepson et al., 2003; Fernández et al., 2005). In this scenario, the rate of ascent would need to be sufficiently rapid to compromise behavioral or physiological protections against nitrogen bubble formation.

Although theoretical predictions suggest the possibility for acoustically mediated bubble growth, there is considerable disagreement among scientists as to its likelihood (Piantadosi and Thalmann, 2004). Sound exposure levels predicted to cause in vivo bubble formation within diving cetaceans have not been evaluated and are suspected as needing to be very high (Evans, 2002; Crum et al., 2005). Moore and Early (2004) reported that in analysis of sperm whale bones spanning 111 years, gas embolism symptoms were observed indicating that sperm whales may be susceptible to decompression sickness due to natural diving behavior. Further, although it has been argued that traumas from recent beaked whale strandings are consistent with gas emboli and bubble-induced tissue separations (Jepson et al., 2003), there is no conclusive evidence supporting this hypothesis and there is concern that at least some of the pathological findings (e.g., bubble emboli) are artifacts of the necropsy. Currently, stranding networks in the United States have agreed to adopt a set of necropsy guidelines to determine, in part, the possibility and frequency with which bubble emboli can be introduced into marine mammals during necropsy procedures (Arruda et al., 2007).

2004 Hawai'i Melon-Headed Whale Mass Stranding (July 3-4 2004)

Description: The majority of the following information is taken from NMFS report on the stranding event (Southall et al., 2006). On the morning of July 3, 2004, between 150–200 melon-headed whales (*Peponocephala electra*) entered Hanalei Bay, Kauai. Individuals attending a canoe blessing ceremony observed the animals entering the bay at approximately 7:00 a.m. The whales were reported entering the bay in a “wave as if they were chasing fish” (Braun 2005). At 6:45 a.m. on July 3, 2004, approximately 46.3 km (25 [NM]) north of Hanalei Bay, active sonar was tested briefly prior to the start of an anti-submarine warfare exercise.

The whales stopped in the southwest portion of the bay, grouping tightly, and displayed spy-hopping and tail-slapping behavior. As people went into the water among the whales, the pod separated into as many as four groups, with individual animals moving among the clusters. This continued through most of the day, with the animals slowly moving south and then southeast within the bay. By about 3 p.m., police arrived and kept people from interacting with the animals. At 4:45 p.m. on July 3, 2004, the RIMPAC Battle Watch Captain received a call from a National Marine Fisheries representative in Honolulu, Hawaii, reporting the sighting of as many as 200 melon-headed whales in Hanalei Bay. At 4:47 p.m. the Battle Watch Captain directed all ships in the area to cease active sonar transmissions.

At 7:20 p.m. on July 3, 2004, the whales were observed in a tight single pod 68.6 m (75 yards) from the southeast side of the bay. The pod was circling in a group and displayed frequent tail slapping and whistle vocalizations and some spy hopping. No predators were observed in the bay and no animals were reported as having fresh injuries. The pod stayed in the bay through the night of July 3, 2004. On the morning of July 4, 2004, the whales were observed to still be in the bay and collected in a tight group. A decision was made at that time to attempt to herd the animals out of the bay. A 700-to-800-foot rope was constructed by weaving together beach morning glory vines. This vine rope was tied between two canoes and with the assistance of 30 to 40 kayaks, was used to herd the animals out of the bay. By approximately 11:30 a.m. on July 4, 2004, the pod was coaxed out of the bay.

A single neonate melon-headed whale was observed in the bay on the afternoon of July 4, after the whale pod had left the bay. The following morning on July 5, 2004, the neonate was found stranded on Lumahai Beach. It was pushed back into the water but was found stranded dead between 9 and 10 a.m. near the Hanalei pier. NMFS collected the carcass and had it shipped to California for necropsy, tissue collection, and diagnostic imaging. This small calf was the only known mortality during the stranding event (Southall, 2008).

Following the stranding event, NMFS undertook an investigation of possible causative factors of the stranding. This analysis included available information on environmental factors, biological factors, and an analysis of the potential for sonar involvement. The latter analysis included vessels that utilized mid-frequency active sonar on the afternoon and evening of July 2. These vessels were to the southeast of Kauai, on the opposite side of the island from Hanalei Bay.

Findings: An NMFS’ official declared that the location of the animals prior to their entering the bay is unknown. Furthermore, the potential exposure and behavioral response by the whales is also unknown. In their report, a spatial analysis indicated that the requisite transit time from the general operational area on July 2 to Hanalei Bay on July 3 was reasonably consistent with the swimming speed of many pelagic cetaceans (Southall, 2008). Sound transmissions by ships to the north of Hanalei Bay on July 3 were produced as part of exercises between 6:45 a.m. and 4:47 p.m. Propagation analysis conducted by the 3rd Fleet estimated that the level of sound from these transmissions at the mouth of Hanalei Bay could have ranged from 138-149 dB re 1 μPa.

No known significant atmospheric, oceanographic, or seismic events occurred in the area during the period of time when this event occurred. The animals make no known feeding attempts while in the Bay (Southall, 2008). However, additional analysis by Navy investigators found that a full moon occurred the evening before the stranding and was coupled with a squid run. In addition, a group of 500-700 melon-headed whales were observed to come close to shore and interact with humans in Sasanhaya Bay, Rota, on the same morning as the whales entered Hanalei Bay (Jefferson et al., 2006). Previous records further indicated that, though the entrance of melon-headed whales into the shallows is rare, it is not unprecedented. A pod of melon-headed whales entered Hilo Bay in the 1870s in a manner similar to that which occurred at Hanalei Bay in 2004.

The necropsy of the melon-headed whale calf suggested that the animal died from a lack of nutrition, possibly following separation from its mother. NMFS concluded that the cause of mortality was likely to result from poor nutritional condition arising from the cow-calf separation (Southall, 2008). The calf was estimated to be approximately one week old. Although the calf appeared not to have eaten for some time, it was not possible to determine whether the calf had ever nursed after it was born. The calf showed no signs of blunt trauma or viral disease and had no indications of acoustic injury.

Conclusions: Although it is not impossible, it is unlikely that the sound level from the sonar caused the melon-headed whales to enter Hanalei Bay. This conclusion is based on a number of factors:

The speculation that the whales may have been exposed to sonar the day before and then fled to the Hanalei Bay is not supported by reasonable expectation of animal behavior and swim speeds. The flight response of the animals would have had to persist for many hours following the cessation of sonar transmissions. Such responses have not been observed in marine mammals and no documentation of such persistent flight response after the cessation of a frightening stimulus has been observed in other mammals. The swim speeds, though feasible for the species, are highly unlikely to be maintained for the durations proposed, particularly since the pod was a mixed group containing both adults and neonates. Whereas adults may maintain a swim speed of 4.0 m/sec (8.9 mi/hr) for some time, it is improbable that a neonate could achieve the same for a period of many hours.

The area between the islands of Oahu and Kauai and the PMRF training range have been used in RIMPAC exercises for more than 20 years, and are used year-round for ASW training using mid frequency active sonar. Melon-headed whales inhabiting the waters around Kauai are likely not naive to the sound of sonar and there has never been another stranding event associated in time with ASW training at Kauai or in the Hawaiian Islands. Similarly, the waters surrounding Hawaii contain an abundance of marine mammals, many of which would have been exposed to the same sonar operations that were speculated to have affected the melon-headed whales. No other strandings were reported coincident with the RIMPAC exercises. This leaves it uncertain as to why melon-headed whales, and no other species of marine mammal, would respond to the sonar exposure by stranding.

At the nominal swim speed for melon-headed whales, the whales had to be 2.8 to 3.7 km (1.5 to 2.0 NM) of Hanalei Bay before sonar was activated on July 3. The whales were not in their open ocean habitat but had to be close to shore at 6:45 a.m. when the sonar was activated to have been observed inside Hanalei Bay from the beach by 7:00 a.m. (Hanalei Bay is very large area). This observation suggests that other potential factors could be causative of the stranding event (see below).

The simultaneous movement of 500-700 melon-headed whales and Risso's dolphins into Sasanhaya Bay, Rota, in the Northern Marianas Islands on the same morning as the 2004 Hanalei stranding (Jefferson et al., 2006) suggests that there may be a common factor which prompted the melon-headed whales to approach the shoreline. A full moon occurred the evening before the stranding and a run of squid was reported concomitant with the lunar activity (ref). Thus, it is possible that the melon-headed whales were capitalizing on a lunar event that provided an opportunity for relatively easy prey capture. A report of a pod entering Hilo Bay in the 1870s indicates that on at least one other occasion, melon-headed whales entered a bay in a manner similar to the occurrence at Hanalei Bay in July 2004. Thus, although melon-headed whales entering shallow embayments may be an infrequent event, and every such event might be considered anomalous, there is precedent for the occurrence.

The received noise sound levels at the bay were estimated to range from roughly 95–149 dB re 1 μPa. Received levels as a function of time of day have not been reported, so it is not possible to determine when the presumed highest levels would have occurred and for how long. However, received levels in the upper range would have been audible by human participants in the bay. The statement by one interviewee that he heard "pings" that lasted an hour and that they were loud enough to hurt his ears is unreliable. Received levels necessary to cause pain over the duration stated would have been observed by most individuals in the water with the animals. No other such reports were obtained from people interacting with the animals in the water.

Although NMFS concluded that sonar use was a "plausible, if not likely, contributing factor in what may have been a confluence of events (Southall et al., 2006)," this conclusion was based primarily on the basis that there was an absence of any other compelling explanation. The authors of NMFS report on the incident were unaware, at the time of publication, of the simultaneous event in Rota. In light of the simultaneous Rota event, the Hanalei stranding does not appear as anomalous as initially presented and the speculation that sonar was a causative factor is weakened. The Hanalei Bay incident does not share the characteristics observed with other mass strandings of whales coincident with sonar activity (e.g., specific traumas, species composition, etc.). In addition, the inability to conclusively link or exclude the impact of other environmental factors makes a causal link between sonar and the melon-headed whale strandings highly speculative at best.

2006 Spain, Gulf of Vera Beaked Whale Mass Stranding (26-27 January 2006)

Description: The Spanish Cetacean Society reported an atypical mass stranding of four beaked whales that occurred January 26 to 28, 2006, on the southeast coast of Spain near Mojacar (Gulf of Vera) in the Western Mediterranean Sea. According to the report, two of the whales were discovered the evening of January 26 and were found to be still alive. Two other whales were discovered during the day on January 27, but had already died. A following report stated that the first three animals were located near the town of Mojacar and were examined by a team from the University of Las Palmas de Gran Canarias, with the help of the stranding network of Ecologistas en Acción Almería-PROMAR and others from the Spanish Cetacean Society. The fourth animal was found dead on the afternoon of May 27, a few kilometers north of the first three animals.

From January 25-26, 2006, a NATO surface ship group (seven ships including one U.S. ship under NATO operational command) conducted active sonar training against a Spanish submarine within 92.6 km (50 nautical miles [NM]) of the stranding site.

Findings: Veterinary pathologists necropsied the two male and two female beaked whales (*Z. cavirostris*).

Conclusions: According to the pathologists, a likely cause of this type of beaked whale mass stranding event may have been anthropogenic acoustic activities. However, no detailed pathological results confirming this supposition have been published to date, and no positive acoustic link was established as a direct cause of the stranding.

Even though no causal link can be made between the stranding event and naval exercises, certain conditions may have existed in the exercise area that, in their aggregate, may have contributed to the marine mammal strandings (Freitas, 2004):

- Operations were conducted in areas of at least 1,000 meters (3,281 ft) in depth near a shoreline where there is a rapid change in bathymetry on the order of 1,000–6,000 meters (3,281–19,685 ft) occurring a cross a relatively short horizontal distance (Freitas, 2004).
- Multiple ships, in this instance, five MFA sonar equipped vessels, were operating in the same area over extended periods of time (20 hours) in close proximity.
- Exercises took place in an area surrounded by landmasses, or in an embayment. Operations involving multiple ships employing mid-frequency active sonar near land may produce sound directed towards a channel or embayment that may cut off the lines of egress for marine mammals (Freitas, 2004).

Other Global Stranding Discussions

In the following sections, stranding events that have been linked to DON activity in popular press are presented. As detailed in the individual case study conclusions, the DON believes that there is enough to evidence available to refute allegations of impacts from mid-frequency sonar, or at least indicate that a substantial degree of uncertainty in time and space that preclude a meaningful scientific conclusion.

Stranding Events Case Studies

2003 Washington State Harbor Porpoise Strandings (May 2 – June 2 2003)

Description: At 1040 hours on May 5, 2003, the USS Shoup began the use of mid-frequency tactical active sonar as part of a naval exercise. At 1420, the USS Shoup entered the Haro Strait and terminated active sonar use at 1438, thus limiting active sonar use within the strait to less than 20 minutes. Between May 2 and June 2, 2003, approximately 16 strandings involving 15 harbor porpoises (*Phocoena phocoena*) and one Dall's porpoise (*Phocoenoides dalli*) were reported to the Northwest Marine Mammal Stranding Network. A comprehensive review of all strandings and the events involving USS Shoup on 5 May 2003 were presented in U.S.

Department of Navy (2004). Given that the USS Shoup was known to have operated sonar in the strait on May 5, and that supposed behavioral reactions of killer whales (*Orcinus orca*) had been putatively linked to these sonar operations (NMFS Office of Protected Resources, 2005), NMFS undertook an analysis of whether sonar caused the strandings of the harbor porpoises.

Ten whole carcasses of harbor porpoises and the head of an additional porpoise were collected for analysis. Necropsies were performed on ten of the harbor porpoises and six whole carcasses and two heads were selected for CT imaging. Gross examination, histopathology, age determination, blubber analysis, and various other analyses were conducted on each of the carcasses (Norman et al., 2004).

<u>Findings</u>: Post-mortem findings and analysis details are found in Norman et al. (2004). All of the carcasses suffered from some degree of freeze-thaw artifact that hampered gross and histological evaluations. At the time of necropsy, three of the porpoises were moderately fresh, whereas the remainder of the carcasses was considered to have moderate to advanced decomposition. None of the 11 harbor porpoises demonstrated signs of acoustic trauma. In contrast, a putative cause of death was determined for 5 of the porpoises; 2 animals had blunt trauma injuries and 3 animals had indication of disease processes (fibrous peritonitis, salmonellosis, and necrotizing pneumonia). A cause of death could not be determined in the remaining animals, which is consistent with expected percentage of marine mammal necropsies conducted within the northwest region. It is important to note, however, that these determinations were based only on the evidence from the necropsy so as not to be biased with regard to determinations of the potential presence or absence of acoustic trauma. The result was that other potential causal factors, such as one animal (Specimen 33NWR05005) found tangled in a fishing net, was unknown to the investigators in their determination regarding the likely cause of death.

<u>Conclusions</u>: NMFS concluded from a retrospective analysis of stranding events that the number of harbor porpoise stranding events in the approximate month surrounding the USS Shoup use of sonar was higher than expected based on annual strandings of harbor porpoises (Norman et al., 2004). In this regard, it is important to note that the number of strandings in the May-June timeframe in 2003 was also higher for the outer coast indicating a much wider pheneomoenaphenomena than use of sonar by USS Shoup in Puget Sound for one day in May. The conclusion by NMFS that the number of strandings in 2003 was higher is also different from that of The Whale Museum, which has documented and responded to harbor porpoise strandings since 1980 (Osborne, 2003). According to The Whale Museum, the number of strandings as of May 15, 2003, was consistent with what was expected based on historical stranding records and was less than that occurring in certain years. For example, since 1992 the San Juan Stranding Network has documented an average of 5.8 porpoise strandings per year. In 1997 there were 12 strandings in the San Juan Islands with more than 30 strandings throughout the general Puget Sound area. Disregarding the discrepancy in the historical rate of porpoise strandings and its relation to the USS Shoup, NMFS acknowledged that the intense level of media attention focused on the strandings likely resulted in an increased reporting effort by the public over that which is normally observed (Norman et al., 2004). NMFS also noted in its report that the "sample size is too small and biased to infer a specific relationship with respect to sonar usage and subsequent strandings."

Seven of the porpoises collected and analyzed died prior to Shoup departing to sea on May 5, 2003. Of these seven, one, discovered on May 5, 2003, was in a state of moderate decomposition, indicating it died before May 5; the cause of death was determined to be due, most likely, to salmonella septicemia. Another porpoise, discovered at Port Angeles on May 6, 2003, was in a state of moderate decomposition, indicating that this porpoise also died prior to May 5. One stranded harbor porpoise discovered fresh on May 6 is the only animal that could potentially be linked in time to the USS Shoup's May 5 active sonar use. Necropsy results for this porpoise found no evidence of acoustic trauma. The remaining eight strandings were discovered one to three weeks after the USS Shoup's May 5 transit of the Haro Strait, making it difficult to causally link the sonar activities of the USS Shoup to the timing of the strandings. Two of the eight porpoises died from blunt trauma injury and a third suffered from parasitic infestation, which possibly contributed to its death (Norman et al., 2004). For the remaining five porpoises, NMFS was unable to identify the causes of death.

The speculative association of the harbor porpoise strandings to the use of sonar by the USS Shoup is inconsistent with prior stranding events linked to the use of mid-frequency sonar. Specifically, in prior events, the stranding of whales occurred over a short period of time (less than 36 hours), stranded individuals were spatially co-located, traumas in stranded animals were consistent between events, and active sonar was known or suspected to be in use. Although mid-frequency active sonar was used by the USS Shoup, the distribution of harbor porpoise strandings by location and with respect to time surrounding the event do not support the suggestion that mid-frequency active sonar was a cause of harbor porpoise strandings. Rather, a complete lack of evidence of any acoustic trauma within the harbor porpoises, and the identification of probable causes of stranding or death in several animals, further supports the conclusion that harbor porpoise strandings were unrelated to the sonar activities of the USS Shoup.

Additional allegations regarding USS Shoup use of sonar having caused behavioral effects to Dall's porpoise, orca, and a minke whale also arose in association with this event (see U.S. Department of Navy 2004 for a complete discussion).

Dall's porpoise: Information regarding the observation of Dall's porpoise on May 5, 2003 came from the operator of a whale watch boat at an unspecified location. This operator reported the Dall's porpoise were seen "going north" when the Shoup was estimated by him to be 10 miles away. Potential reasons for the Dall's movement include the pursuit of prey, the presence of harassing resident orca or predatory transient orca, vessel disturbance from one of many whale watch vessels, or multiple other unknowable reasons including the use of sonar by USS Shoup. In short, there was nothing unusual in the observed behavior of the Dall's porpoise on May 5, 2003 and no way to assess if the otherwise normal behavior was in reaction to the use of sonar by USS Shoup, any other potential causal factor, or a combination of factors.

Orca: Observer opinions regarding orca J-Pod behaviors on May 5, 2003 were inconsistent, ranging from the orca being "at ease with the sound" or "resting" to their being "annoyed." One witness reported observing "low rates of surface active behavior" on behalf of the orca J-Pod, which is in conflict with that of another observer who reported variable surface activity, tail slapping and spyhopping. Witnesses also expressed the opinion that the behaviors displayed by the orca on May 5, 2003 were "extremely unusual," although those same behaviors are observed and reported regularly on the Orca Network Website, are behaviors listed in general references as being part of the normal repertoire of orca behaviors. Given the contradictory nature of the reports on the observed behavior of the J-Pod orca, it is impossible to determine if any unusual behaviors were present. In short, there is no way to assess if any unusual behaviors were present or if present they were in reaction to vessel disturbance from one of many nearby whale watch vessels, use of sonar by USS Shoup, any other potential causal factor, or a combination of factors.

Minke whale: A minke whale was reported porpoising in Haro Strait on May 5, 2003, which is a rarely observed behavior. The cause of this behavior is indeterminate given multiple potential causal factors including but not limited to the presence of predatory Transient orca, possible interaction with whale watch boats, other vessels, or Shoup's use of sonar. The behavior of the minke whale was the only unusual behavior clearly present on May 5, 2003, however, no way to given the existing information if the unusual behavior observed was in reaction to the use of sonar by USS Shoup, any other potential causal factor, or a combination of factors.

2004 Hawai'i Melon-Headed Whale Mass Stranding (July 3-4 2004)

Description: The majority of the following information is taken from NMFS report on the stranding event (Southall et al., 2006). On the morning of July 3, 2004, between 150–200 melon-headed whales (*Peponocephala electra*) entered Hanalei Bay, Kauai. Individuals attending a canoe blessing ceremony observed the animals entering the bay at approximately 7:00 a.m. The whales were reported entering the bay in a "wave as if they were chasing fish" (Braun 2005). At 6:45 a.m. on July 3, 2004, approximately 46.3 km (25 [NM]) north of Hanalei Bay, active sonar was tested briefly prior to the start of an anti-submarine warfare exercise.

The whales stopped in the southwest portion of the bay, grouping tightly, and displayed spy-hopping and tail-slapping behavior. As people went into the water among the whales, the pod separated into as many as four groups, with individual animals moving among the clusters. This continued through most of the day, with the animals slowly moving south and then southeast within the bay. By about 3 p.m., police arrived and kept people from interacting with the animals. At 4:45 p.m. on July 3, 2004, the RIMPAC Battle Watch Captain received a call from a National Marine Fisheries representative in Honolulu, Hawaii, reporting the sighting of as many as 200 melon-headed whales in Hanalei Bay. At 4:47 p.m. the Battle Watch Captain directed all ships in the area to cease active sonar transmissions.

At 7:20 p.m. on July 3, 2004, the whales were observed in a tight single pod 68.6 m (75 yards) from the southeast side of the bay. The pod was circling in a group and displayed frequent tail slapping and whistle vocalizations and some spy hopping. No predators were observed in the bay and no animals were reported as having fresh injuries. The pod stayed in the bay through the night of July 3, 2004. On the morning of July 4, 2004, the whales were observed to still be in the bay and collected in a tight group. A decision was made at that time to attempt to herd the animals out of the bay. A 700-to-800-foot rope was constructed by weaving together beach morning glory vines. This vine rope was tied between two canoes and with the assistance of 30 to 40 kayaks, was used to herd the animals out of the bay. By approximately 11:30 a.m. on July 4, 2004, the pod was coaxed out of the bay.

A single neonate melon-headed whale was observed in the bay on the afternoon of July 4, after the whale pod had left the bay. The following morning on July 5, 2004, the neonate was found stranded on Lumahai Beach. It was pushed back into the water but was found stranded dead between 9 and 10 a.m. near the Hanalei pier. NMFS collected the carcass and had it shipped to California for necropsy, tissue collection, and diagnostic imaging.

Following the stranding event, NMFS undertook an investigation of possible causative factors of the stranding. This analysis included available information on environmental factors, biological factors, and an analysis of the potential for sonar involvement. The latter analysis included vessels that utilized mid-frequency active sonar on the afternoon and evening of July 2. These vessels were to the southeast of Kauai, on the opposite side of the island from Hanalei Bay.

Findings: NMFS concluded from the acoustic analysis that the melon-headed whales would have had to have been on the southeast side of Kauai on July 2 to have been exposed to sonar from naval vessels on that day (Southall et al., 2006). There was no indication whether the animals were in that region or whether they were elsewhere on July 2. NMFS concluded that the animals would have had to swim from 1.4-4.0 meters per second (m/sec) (3.1–8.9 miles per hour [mi/hr]) for 6.5 to 17.5 hours after sonar transmissions ceased to reach Hanalei Bay by 7:00 a.m. on July 3. Sound transmissions by ships to the north of Hanalei Bay on July 3 were produced as part of exercises between 6:45 a.m. and 4:47 p.m. Propagation analysis conducted by the 3rd Fleet estimated that the level of sound from these transmissions at the mouth of Hanalei Bay could have ranged from 138-149 dB re 1 μPa.

NMFS was unable to determine any environmental factors (e.g., harmful algal blooms, weather conditions) that may have contributed to the stranding. However, additional analysis by Navy investigators found that a full moon occurred the evening before the stranding and was coupled with a squid run (ref). In addition, a group of 500-700 melon-headed whales were observed to come close to shore and interact with humans in Sasanhaya Bay, Rota, on the same morning as the whales entered Hanalei Bay (Jefferson et al., 2006). Previous records further indicated that, though the entrance of melon-headed whales into the shallows is rare, it is not unprecedented. A pod of melon-headed whales entered Hilo Bay in the 1870s in a manner similar to that which occurred at Hanalei Bay in 2004.

The necropsy of the melon-headed whale calf suggested that the animal died from a lack of nutrition, possibly following separation from its mother. The calf was estimated to be approximately one week old. Although the calf appeared not to have eaten for some time, it was not possible to determine whether the calf had ever nursed after it was born. The calf showed no signs of blunt trauma or viral disease and had no indications of acoustic injury.

Conclusions: Although it is not impossible, it is unlikely that the sound level from the sonar caused the melon-headed whales to enter Hanalei Bay. This conclusion is based on a number of factors:

The speculation that the whales may have been exposed to sonar the day before and then fled to the Hanalei Bay is not supported by reasonable expectation of animal behavior and swim speeds. The flight response of the animals would have had to persist for many hours following the cessation of sonar transmissions. Such responses have not been observed in marine mammals and no documentation of such persistent flight response after the cessation of a frightening stimulus has been observed in other mammals. The swim speeds, though feasible for the species, are highly unlikely to be maintained for the durations proposed, particularly since the pod was a mixed group containing both adults and neonates. Whereas adults may maintain a swim speed of

4.0 m/sec (8.9 mi/hr) for some time, it is improbable that a neonate could achieve the same for a period of many hours.

The area between the islands of Oahu and Kauai and the PMRF training range have been used in RIMPAC exercises for more than 20 years, and are used year-round for ASW training using mid frequency active sonar. Melon-headed whales inhabiting the waters around Kauai are likely not naive to the sound of sonar and there has never been another stranding event associated in time with ASW training at Kauai or in the Hawaiian Islands. Similarly, the waters surrounding Hawaii contain an abundance of marine mammals, many of which would have been exposed to the same sonar operations that were speculated to have affected the melon-headed whales. No other strandings were reported coincident with the RIMPAC exercises. This leaves it uncertain as to why melon-headed whales, and no other species of marine mammal, would respond to the sonar exposure by stranding.

At the nominal swim speed for melon-headed whales, the whales had to be 2.8 to 3.7 km (1.5 to 2.0 NM) of Hanalei Bay before sonar was activated on July 3. The whales were not in their open ocean habitat but had to be close to shore at 6:45 A.M. when the sonar was activated to have been observed inside Hanalei Bay from the beach by 7:00 A.M (Hanalei Bay is very large area). This observation suggests that other potential factors could be causative of the stranding event (see below).

The simultaneous movement of 500-700 melon-headed whales and Risso's dolphins into Sasanhaya Bay, Rota, in the Northern Marianas Islands on the same morning as the 2004 Hanalei stranding (Jefferson et al., 2006) suggests that there may be a common factor which prompted the melon-headed whales to approach the shoreline. A full moon occurred the evening before the stranding and a run of squid was reported concomitant with the lunar activity (ref). Thus, it is possible that the melon-headed whales were capitalizing on a lunar event that provided an opportunity for relatively easy prey capture. A report of a pod entering Hilo Bay in the 1870s indicates that on at least one other occasion, melon-headed whales entered a bay in a manner similar to the occurrence at Hanalei Bay in July 2004. Thus, although melon-headed whales entering shallow embayments may be an infrequent event, and every such event might be considered anomalous, there is precedent for the occurrence.

The received noise sound levels at the bay were estimated to range from roughly 95–149 dB re 1 µPa. Received levels as a function of time of day have not been reported, so it is not possible to determine when the presumed highest levels would have occurred and for how long. However, received levels in the upper range would have been audible by human participants in the bay. The statement by one interviewee that he heard "pings" that lasted an hour and that they were loud enough to hurt his ears is unreliable. Received levels necessary to cause pain over the duration stated would have been observed by most individuals in the water with the animals. No other such reports were obtained from people interacting with the animals in the water.

Although NMFS concluded that sonar use was a "plausible, if not likely, contributing factor in what may have been a confluence of events (Southall et al., 2006)," this conclusion was based primarily on the basis that there was an absence of any other compelling explanation. The authors of NMFS report on the incident were unaware, at the time of publication, of the simultaneous event in Rota. In light of the simultaneous Rota event, the Hanalei stranding does not appear as anomalous as initially presented and the speculation that sonar was a causative factor is weakened. The Hanalei Bay incident does not share the characteristics observed with other mass strandings of whales coincident with sonar activity (e.g., specific traumas, species composition, etc.). In addition, the inability to conclusively link or exclude the impact of other environmental factors makes a causal link between sonar and the melon-headed whale strandings highly speculative at best.

1980- 2004 Beaked Whale Strandings in Japan (Brownell et al. 2004)

Description: Brownell et al. (2004) compare the historical occurrence of beaked whale strandings in Japan (where there are U.S. Naval bases), with strandings in New Zealand (which lacks a U.S. Naval base) and concluded the higher number of strandings in Japan may be related to the presence of the US. Navy vessels using mid-frequency sonar. While the dates for the strandings were well documented, the authors of the study did not attempt to correlate the dates of any navy activities or exercises with the dates of the strandings.
To fully investigate the allegation made by Brownell et al. (2004), the Center for Naval Analysis (CNA) looked at the past U.S. Naval exercise schedules from 1980 to 2004 for the water around Japan in comparison to the dates for the strandings provided by Brownell et al. (2004). None of the strandings occurred during or soon (within weeks) after any DON exercises. While the CNA analysis began by investigating the probabilistic nature of any co-occurrences, the results were a 100 percent probability the strandings and sonar use were not correlated by time. Given there there there was no instance of co-occurrence in over 20 years of stranding data, it can be reasonably postulated that sonar use in Japan waters by DON vessels did not lead to any of the strandings documented by Brownell et al. (2004).

2004 Alaska Beaked Whale Strandings (7-16 June 2004)

Description: In the timeframe between 17 June and 19 July 2004, five beaked whales were discovered at various locations along 1,600 miles of the Alaskan coastline and one was found floating (dead) at sea. Because the Navy exercise Alaska Shield/Northern Edge 2004 occurred within the approximate timeframe of these strandings, it has been alleged that sonar may have been the probable cause of these strandings.

The Alaska Shield/Northern Edge 2004 exercise consisted of a vessel tracking event followed by a vessel boarding search and seizure event. There was no ASW component to the exercise, no use of mid-frequency sonar, and no use of explosives in the water. There were no events in the Alaska Shield/Northern Edge exercise that could have caused in any of the strandings over this 33 day period covering 1,600 miles of coastline.

2005 North Carolina Marine Mammal Mass Stranding Event (January 15-16, 2005)

Description: On January 15 and 16, 2005, 36 marine mammals consisting of 33 short-finned pilot whales, 1 minke whale, and 2 dwarf sperm whales stranded alive on the beaches of North Carolina (Hohn et al., 2006a). The animals were scattered across a 111- km (69 mi) area from Cape Hatteras northward. Because of the live stranding of multiple species, the event was classified as a UME. It is the only stranding on record for the region in which multiple offshore species were observed to strand within a two- to three-day period.

The DON indicated that from January 12-14 some unit level training with mid-frequency active sonar was conducted by vessels that were 93 to 185 km (50 to 100 NM) from Oregon Inlet. An expeditionary strike group was also conducting exercises to the southeast, but the closest point of active sonar transmission to the inlet was 650 km (351 NM) away. The unit level operations were not unusual for the area or time of year and the vessels were not involved in antisubmarine warfare exercises. Marine mammal observers on board the vessels did not detect any marine mammals during the period of unit level training. No sonar transmissions were made on January 15-16.

The National Weather Service reported that a severe weather event moved through North Carolina on January 13 and 14 (Figure 4). The event was caused by an intense cold front that moved into an unusually warm and moist air mass that had been persisting across the eastern United States for about a week. The weather caused flooding in the western part of the state, considerable wind damage in central regions of the state, and at least three tornadoes that were reported in the north central part of the state. Severe, sustained (one to four days) winter storms are common for this region.

Over a two-day period (January 16-17), 2 dwarf sperm whales, 27 pilot whales, and the minke whale were necropsied and tissue samples collected. Twenty-five of the stranded cetacean heads were examined; two pilot whale heads and the heads of the dwarf sperm whales were analyzed by CT.

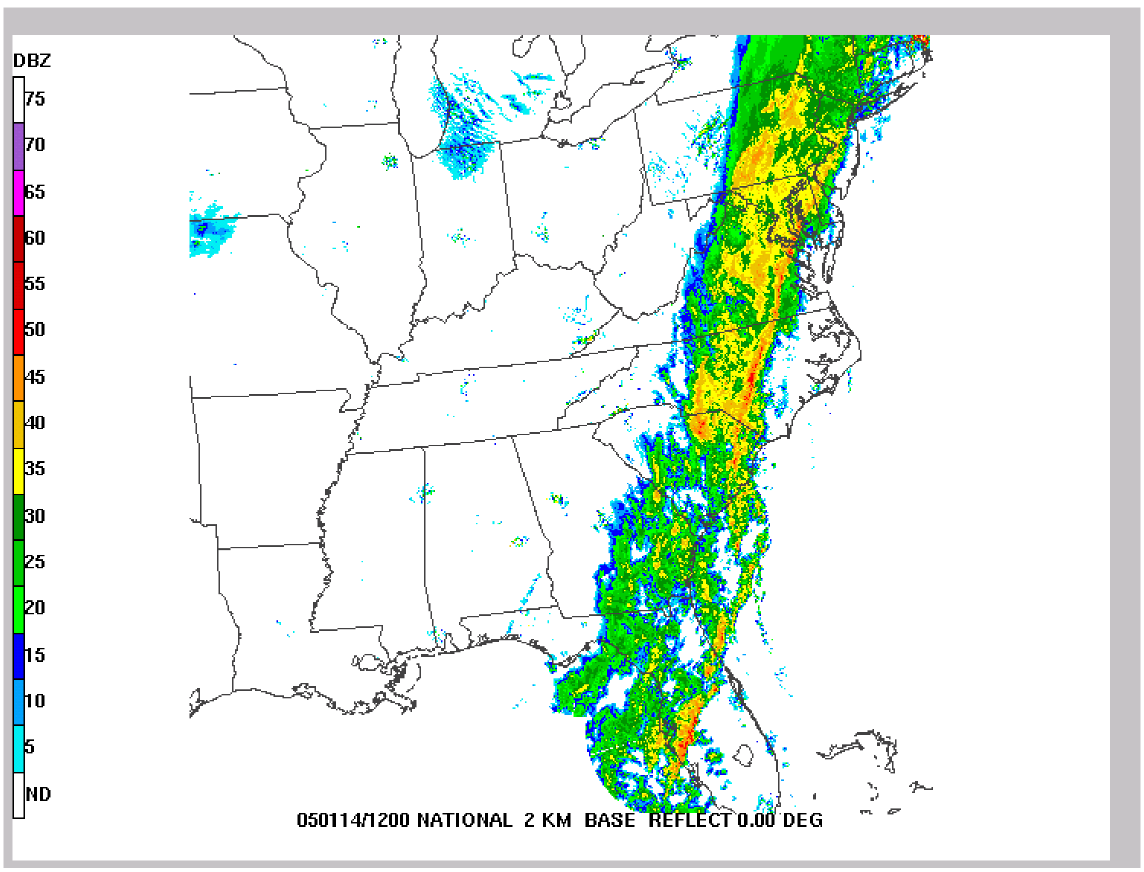


Figure D-4. Regional Radar Imagery for the East Coast (including North Carolina) on January 14, 2005

(The time of the image is approximately 7:00 A.M.)

Findings: The pilot whales and dwarf sperm whale were not emaciated, but the minke whale, which was believed to be a dependent calf, was emaciated. Many of the animals were on the beach for an extended period of time prior to necropsy and sampling, and many of the biochemical abnormalities noted in the animals were suspected of being related to the stranding and prolonged time on land. Lesions were observed in all of the organs, but there was no consistency across species. Musculoskeletal disease was observed in two pilot whales and cardiovascular disease was observed in one dwarf sperm whale and one pilot whale. Parasites were a common finding in the pilot whales and dwarf sperm whales but were considered consistent with the expected parasite load for wild odontocetes. None of the animals exhibited traumas similar to those observed in prior stranding events associated with mid-frequency sonar activity. Specifically, there was an absence of auditory system trauma and no evidence of distributed and widespread bubble lesions or fat emboli, as was previously observed (Fernández et al., 2005).

Sonar transmissions prior to the strandings were limited in nature and did not share the concentration identified in previous events associated with mid-frequency active sonar use (Evans and England, 2001). The operational/environmental conditions were also dissimilar (e.g., no constrictive channel and a limited number of ships and sonar transmissions). NMFS noted that environmental conditions were favorable for a shift from up-welling to down-welling conditions, which could have contributed to the event. However, other severe storm conditions existed in the days surrounding the strandings and the impact of these weather conditions on at-sea conditions is unknown. No harmful algal blooms were noted along the coastline.

Conclusions: All of the species involved in this stranding event are known to occasionally strand in this region. Although the cause of the stranding could not be determined, several whales had preexisting conditions that could have contributed to the stranding. Cause of death for many of the whales was likely due to the physiological stresses associated with being stranded. A consistent suite of injuries across species, which was consistent with prior strandings where sonar exposure is expected to be a causative mechanism, was not observed.

NMFS was unable to determine any causative role that sonar may have played in the stranding event. The acoustic modeling performed, as in the Hanalei Bay incident, was hampered by uncertainty regarding the location of the animals at the time of sonar transmissions. However, as in the Hanalei Bay incident, the response of the animals following the cessation of transmissions would imply a flight response that persisted for many hours after the sound source was no longer operational. In contrast, the presence of a severe weather event passing through North Carolina during January 13 and 14 is a possible, if not likely, contributing factor to the North Carolina UME of January 15.

STRANDING SECTION CONCLUSIONS

Marine mammal strandings have been a historic and ongoing occurrence attributed to a variety of causes. Over the last fifty years, increased awareness and reporting has lead to more information about species effected and raised concerns about anthropogenic sources of stranding. While there has been some marine mammal mortalities potentially associated with mid-frequency sonar effects to a small number of species (primarily limited numbers of certain species of beaked whales), the significance and actual causative reason for any impacts is still subject to continued investigation.

By comparison and as described previously, potential impacts to all species of cetaceans worldwide from fishery related mortality can be orders of magnitude more significant (100,000s of animals versus 10s of animals) (Culik, 2002; ICES, 2005b; Read et al., 2006). This does not negate the influence of any mortality or additional stressor to small, regionalized sub-populations which may be at greater risk from human related mortalities (fishing, vessel strike, sound) than populations with larger oceanic level distribution or migrations. ICES (2005a) noted, however, that taken in context of marine mammal populations in general, sonar is not a major threat, or significant portion of the overall ocean noise budget.

In conclusion, a constructive framework and continued research based on sound scientific principles is needed in order to avoid speculation as to stranding causes, and to further our understanding of potential effects or lack of effects from military mid-frequency sonar (Bradshaw et al., 2006; ICES 2005b; Barlow and Gisiner, 2006; Cox et al. 2006).

D.5 REFERENCES

Alexander, J. W., M. A. Solangi, and L. S. Riegel, 1989. "Vertebral osteomyelitis and suspected diskospondylitis in an Atlantic bottlenose dolphin (*Tursiops truncatus*)," Journal of Wildife Diseases 25, 118-121.

Andrew, R. K., B. M. Howe, and J. A. Mercer, 2002. Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California coast. Journal of the Acoustic Society of America 3(2):65-70.

Arruda, J., A. Costidis, S., Cramer, D. R.Ketten, , W. McLellan, E. W. Montie, M. Moore, , and S. Rommel, 2007. "Odontocete Salvage, Necropsy, Ear Extraction, and Imaging Protocols," edited by N. M. Young (Ocean Research, Conservation and Solutions (ORCAS) and ONR), pp. 1-171.

Arveson, P. T. and D. J. Vendittis. 2006. Radiated noise characteristics of a modern cargo ship. Journal of the Acoustic Society of America 107(1):118-129.

Baird, R. W., and S. K. Hooker, 2000. "Ingestion of plastic and unusual prey by a juvenile harbour porpoise," Marine Pollution Bulletin 40, 719-720.

Baird, R. W., P. J. Stacey, D. A. Duffus, and K. M. Langelier, 2002. An evaluation of gray whale (*Eschrichtius robustus*) mortality incidental to fishing operations in British Columbia, Canada. Journal of Cetacean Research and Management 4(3):289-296.

Baird, R. W. and A. M. Gorgone, 2005. False killer whale dorsal fin disfigurements as a possible indicator of long-line fishery interactions in Hawaiian waters. Pacific Science 59(4):593-601.

Barlow, J. and R. Gisiner, 2006. Mitigating, monitoring and assessing the effects of anthropogenic sound on beaked whales. Journal of Cetacean Research and Management 7(3):239-249.

Bauer, G., M. Fuller, , A. Perry, , J. R. Dunn, and J. Zoeger, 1985. "Magnetoreception and biomineralization of magnetite in cetaceans," in Magnetite Biomineralization and Magnetoreception in Organisms: A New Biomagnetism edited by J. L. Kirschvink, D. S. Jones, and B. J. MacFadden (Plenum Press, New York), pp. 489-507.

Bergman, A., A. Bergstrand, , and A. Bignert, 2001. "Renal lesions in Baltic grey seals (*Halichoerus grypus*) and ringed seals (*Phoca hispida botnica*)," Ambio 30, 397-409.

Borell, A., 1993. PCB and DDTs in blubber of cetaceans from the northeastern North Atlantic. Marine Pollution Bulletin 26:146-151.

Brabyn, M., and R. V. C. Frew, 1994. "New Zealand herd stranding sites do not relate to geomagnetic topography," Mar. Mammal Sci. 10, 195-207.

Brabyn, M. W., and I. G. McLean, 1992. "Oceanography and coastal topography of herd-stranding sites for whales in New Zealand," J. Mamm. 73, 469-476.

Bradshaw, C. J., K. Evans, and M. A. Hindell, 2006. "Mass cetacean strandings-a plea for empiricism," Conservation Biology 20, 584-586.

Braun, R.C., 2005. Personal communication via email between Dr. Robert Braun, National Marine Fisheries Service, Pacific Island Fisheries Science Center, Honolulu, Hawaii, and Mr. Conrad Erkelens, U.S. Pacific Fleet, Fleet Environmental Office, Pearl Harbor Hawaii, September 1.

Brodie, E. C., F. M. D. Gulland, D. J. Greig, , M. Hunter, J.Jaakola, J. S. Leger, T. A. Leighfield, and F. M. V. Dolah, 2006. "Domoic acid causes reproductive failure in California sea lions (*Zalophus californianus*)," Marine Mammal Science 22:700–707.

Brownell, R. L., Jr., T. Yamada, J. G. Mead, and A. van Helden, 2004. Mass strandings of Cuvier's beaked whales in Japan: U.S. naval acoustic link?. Unpublished paper SC/56/E37 presented to IWC Scientific Committee, July 2004. 100 pp.

Campagna, C., V. Falabella, M. Lewis., 2007. Entanglement of southern elephant seals in squid fishing gear. Marine Mammal Science 23(2):414-418.

Carretta, J. V., J. Barlow, K. A. Forney, , M. M. Muto, and J. Baker, 2001. U.S. Pacific marine mammal stock assessments: 2001. NOAA Technical Memorandum NOAA-TM-NMFS-SWFWC-317.

Carretta, J. V., T. Price, D. Petersen, and R. Read, 2004. Estimates of marine mammal, sea turtle, and seabird mortality in the California drift gillnet fishery for swordfish and thresher shark, 1996-2002. Marine Fisheries Review 66(2):21-30.

Carretta, J. V., K. A. Forney, M. M. Muto, J. Barlow, , J. Baker, B. Hanson, and M. S. Lowry, 2007. "U.S. Pacific Marine Mammal Stock Assessments: 2006," (NOAA-TM-NMFS-SWFSC-398, National Marine Fisheries Service, Southwest Fisheries Science Center), p. 321.

Chambers, S., and R. N. James, 2005. "Sonar termination as a cause of mass cetacean strandings in Geographe Bay, south-western Australia," in Acoustics 2005, Acoustics in a Changing Environment (Busselton, Western Australia).

Clyne, H., 1999. Computer simulations of interactions between the North Atlantic right whale (Eubalaena glacialis) and shipping.

Cockcroft, V. G., G. Cliff, and G. J. B. Ross, 1989. "Shark predation on Indian Ocean bottlenose dolphins Tursiops truncatus off Natal, South Africa," South African Journal of Zoology 24, 305-310.

Conner, R. C., 2000. "Group living in whales and dolphins," in Cetacean Societies: Field Studies of Dolphins and Whales, edited by J. Mann, R. C. Conner, P. L. Tyack, and H. Whitehead (University of Chicago Press, Chicago), pp. 199-218.

Constantine, R., I. Visser, D. Buurman, R. Buurman, and B. McFadden, 1998. "Killer whale (Orcinus orca) predation on dusky dolphins (*Lagenorhynchus obscurus*) in Kaikoura, New Zealand," Mar. Mammal Sci. 14, 324-330.

Cox, T. M., T. J. Ragen, A. J. Read, E. Vos, R. W. Baird, K. Balcomb, J. Barlow, J. Caldwell, T. Cranford, L. Crum, A. D'Amico, G. D'Spain, A. Fernández, J. Finneran, R. Gentry, W. Gerth, F. Gulland, J. Hildebrand, D. Houser, T. Hullar, P. D. Jepson, D. Ketten, C. D. Macleod, P. Miller, S. Moore, D. C. Mountain, D. Palka, P. Ponganis, S. Rommel, T. Rowles, B. Taylor, P. Tyack, D. Wartzok, R. Gisiner, J. Meads, and L. Benner, 2006. "Understanding the impacts of anthropogenic sound on beaked whales," J. Cetacean Res. Manage. 7, 177-187.

Crocker, D. E., D. P. Costa, B. J. Le Boeuf, P. M. Webb, and D. S. Houser, 2006. "Impacts of *El Niño* on the foraging behavior of female northern elephant seals," Mar. Ecol. Prog. Ser. 309.

Crum, L. A., M. R. Bailey, G. Jingfeng, P. R. Hilmo, S. G. Kargl, and T. J. Matula, 2005. "Monitoring bubble growth in supersaturated blood and tissue *ex vivo* and the relevance to marine mammal bioeffects," Acoustic Research Letters Online 6, 214-220.

Crum, L. A., and Y. Mao, 1996. "Acoustically enhanced bubble growth at low frequencies and its implications for human diver and marine mammal safety," J. Acoust. Soc. Am. 99, 2898-2907.

Culik, B. M., 2002. "Review on Small Cetaceans: Distribution, Behaviour, Migration and Threats," in United Nations Environment Programme, Convention on Migratory Species (Marine Mammal Action Plan/Regional Seas Reports and Studies No. 177), p. 343.

D'Amico, A., and W. Verboom, 1998. "Report of the Bioacoustics Panel, NATO/SACLANT," pp. 2-1-2-60.

D'Spain, G. L., A. D'Amico, and D.M. Fromm., 2006. Properties of the underwater sound fields during some well documented beaked whale mass stranding events. Journal of Cetacean Research and Management 7(3):223-238.

Dailey, M., and W. A. Walker, 1978. "Parasitism as a factor (?) in single strandings of southern California cetaceans," Journal of Parasitology 64, 593-596.

Dailey, M., M. Walsh, D. Odell, and T. Campbell, 1991. "Evidence of prenatal infection in the bottlenose dolphin (Tursiops truncatus) with the lungworm Halocercus lagenorhynchi (Nematoda: Pseudaliidae)," Journal of Wildife Diseases 27, 164-165.

Das, K., V. Debacker, S. Pillet, and J.-M.Bouquegneau, , 2003. "Heavy metals in marine mammals," in Toxicology of Marine Mammals, edited by J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea (Taylor & Francis, London), pp. 135-167.

De Guise, S., K. B. Beckmen, and S. D. Holladay, 2003. "Contaminants and marine mammal immunotoxicology and pathology," in Toxicology of Marine Mammals, edited by J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea (Taylor & Francis, London), pp. 38-54.

De Stephasis, R. and E. Urquiola., 2006). Collisions between ships and cetaceans in Spain. Report to the Scientific Committee, International Whaling Commission SC/58/BC5.

DeMaster, D., C. W. Fowler, S. L. Perry, and M. F. Richlen, 2001. "Predation and competition: The impact of fisheries on marine-mammal populations over the next one hundred years," J. Mamm. 82, 641-651.

Dierauf, L. A., and F. M. D. Gulland, 2001. "Marine Mammal Unusual Mortality Events," in Marine Mammal Medicine, edited by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton), pp. 69-81.

Domingo, M., J. Visa, M. Pumarola, A. J. Marco, L. Ferrer, R. Rabanal, and S. Kennedy, 1992. "Pathologic and immunocytochemical studies of morbillibirus infection in striped dolphins (Stenella coeruleoalba)," Veterinary Pathology 29, 1-10.

Dudok van Heel, W. H., 1966. "Navigation in cetacea," in Whales, Dolphins, and Porpoises, edited by K. S. Norris (University of California Press, Berkeley), pp. 597-606.

Dunn, J. L., J. D. Buck, and T. R. Robeck, 001. "Bacterial diseases of cetaceans and pinnipeds," in Marine Mammal Medicine, edited by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton, FL), pp. 309-335.

Evans, D. L., 2002. "Report of the Workshop on Acoustic Resonance as a Source of Tissue Trauma in Cetaceans," (Silver Spring, MD).

Evans, D. L., and G. R. England, 2001. "Joint Interim Report Bahamas Marine Mammal Stranding Event of 15-16 March 2000," (Department of Commerce), pp. 1-66.

Evans, K., and Mark A. Hindell, 2004). The diet of sperm whales (Physeter macrocephalus) in southern Australian waters. ICES Journal of Marine Science, Vol 61, No 8, pp. 1313 - 1329.

Evans, K., R. Thresher,R. M. Warneke, C. J. A. Bradshaw, M. Pook, D. Thiele, and M. A. Hindell, 2005. "Periodic variability in cetacean strandings: links to large-scale climate events," Biology Letters 1, 147-150.

Fernández, A., J. Edwards, V. Martín, F. Rodríguez, A. Espinosa de los Monteros, P. Herráez, P. Castro, J. R. Jaber, and M. Arbelo, 2005. ""Gas and fat embolic syndrome" involving a mass stranding of beaked whales exposed to anthropogenic sonar signals," Journal of Veterinary Pathology 42, 446-457.

Finneran, J. J., D. A. Carder, , C. E. Schlundt, and S. H. Ridgway, 2005. "Temporary threshold shift (TTS) in bottlenose dolphins (Tursiops truncatus) exposed to mid-frequency tones," J. Acoust. Soc. Am. 118, 2696-2705.

Finneran, J. J., R. Dear, D. A. Carder, and S. H. Ridgway, 2003. "Auditory and behavioral responses of California sea lions (Zalophus californianus) to single underwater impulses from an arc-gap transducer," J. Acoust. Soc. Am. 114, 1667-1677.

Finneran, J. J., C. E. Schlundt, D. A. Carder, J. A. Clark, J. A. Young, J. B. Gaspin, and S. H. Ridgway2000. "Auditory and behavioral responses of bottlenose dolphins (*Tursiops truncatus*) and a beluga whale (*Delphinapterus leucas*) to impulsive sounds resembling distant signatures of underwater explosions," J. Acoust. Soc. Am. 108, 417-431.

Flewelling, L. J., J. P. Naar, J. P. Abbott, D. G. Baden, N. B. Barros, G. D. Bossart, M.-Y. D. Bottein, , D. G. Hammond, E. M. Haubold, C. A. Heil, M. S. Henry, H. M. Jacocks, T. A. Leighfield, R. H. Pierce, T. D. Pitchford, S. A. Rommel, P. S. Scott, K. A. Steidinger, E. W. Truby, F. M. V. Dolah, and J. H. Landsberg, J. H., 2005. "Brevetoxicosis: Red tides and marine mammal mortalities," Nature 435, 755-756.

Frantzis, A., (1998). "Does acoustic testing strand whales?," in Nature, p. 29.

Freitas, L., 2004. "The stranding of three Cuvier's beaked whales Ziphius cavirostris in Madeira Archipelago - May 2000," in European Cetacean Society 17th Annual Conference (Las Palmas, Gran Canaria).

Frodello, J. P., and B. Marchand, 2001. "Cadmium, copper, lead, and zinc in five toothed whale species of the Mediterranean Sea," International Journal of Toxicology 20, 339-343.

Geraci, J. R., 1989. "Clinical investigation of the 1987-88 mass mortality of bottlenose dolphins along the U.S. central and south Atlantic coast," (Final report to the National Marine Fisheries Service, U. S. Navy, Office of Naval Research, and Marine Mammal Commission), pp. 1-63.

Geraci, J.R., and V. J. Lounsbury, 1993. Marine Mammals Ashore: A Field Guide for Strandings. Texas A&M University Sea Grant College Program, Galveston, TX.

Geraci, J. R., J. Harwood, and V. J. Lounsbury, 1999. "Marine mammal die-offs: Causes, investigations, and issues," in Conservation and management of marine mammals, edited by J. R. Twiss, and R. R. Reeves (Smithsonian Institution Press, Washington, DC), pp. 367-395.

Geraci, J. R., and V. J. Lounsbury, 2005. Marine Mammals Ashore: A Field Guide for Strandings (Second Edition) (National Aquarium in Baltimore, Baltimore, MD).

Geraci, J. R., and D. J. St.Aubin, 1987. "Effects of parasites on marine mammals," International Journal of Parasitology 17, 407-414.

Goodson, A.D., 1997. Developing deterrent devices designed to reduce the mortality of small cetaceans in commercial fishing nets. Marine and Freshwater Behaviour and Physiology 29:211-236.

Gorzelany, J. F., 1998. "Unusual deaths of two free-ranging Atlantic bottlenose dolphins (Tursiops truncatus) related to ingestion of recreational fishing gear," Mar. Mammal Sci. 14, 614-617.

Grachev, M. A., V. P. Kumarev, L. V. Mamaev, V. L. Zorin, L. V. Baranova, N. N. Denikina, S. I. Belkov, E. A. Petrov, and V. S. Kolesnik, 1989. "Distemper virus in Baikal seals," Nature 338, 209-210.

Greig, D. J., F. M. D. Gulland, and C. Kreuder, 2005. "A decade of live California sea lion (*Zalophus californianus*) strandings along the central California coast: Causes and trends, 1991-2000," Aquat. Mammals 31, 11-22.

Guinet, C., Barrett-Lennard, L. G., and B. Loyer, 2000. "Co-ordinated attack behavior and prey sharing by killer whales at Crozet Archipelago: strategies for feeding on negatively-buoyant prey," Mar. Mammal Sci. 16, 829-834.

Gulland, F. M. D., 2006. "Review of the Marine Mammal Unusual Mortality Event Response Program of the National Marine Fisheries Service," (Report to the Office of Protected Resources, NOAA/National Marine Fisheries Service, Silver Springs, MD), p. 32.

Gulland, F. M. D., and A. J. Hall, 2005. "The Role of Infectious Disease in Influencing Status and Trends," in Marine Mammal Research, edited by J. E. Reynolds, W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen (John Hopkins University Press, Baltimore), pp. 47-61.

Gulland, F.M.D. and A.J. Hall., 2007. Is marine mammal health deteriorating? Trends in global reporting of marine mammal disease. EcoHealth 4:135-150.

Gulland, F. M. D., M. Koski, L. J. Lowenstine, A. Colagross, L. Morgan, and T. Spraker, 1996. "Leptospirosis in California sea lions (*Zalophus califorianus*) stranded along the central California coast, 1981-1994," Journal of Wildife Diseases 32, 572-580.

Harwood, J., 2002. "Mass Die-offs," in Encyclopedia of Marine Mammals, edited by W. F. Perrin, B. Würsig, and J. G. M. Thewissen (Academic Press, San Diego), pp. 724-726.

Heithaus, M. R., 2001. "Shark attacks on bottlenose dolphins (*Tursiops aduncus*) in Shark Bay, Western Australia: Attack rate, bite scar frequencies and attack seasonality," Mar. Mammal Sci. 17, 526-539.

Heyning, J.E., and T. D. Lewis, 1990 Entanglements of baleen whales in fishing gear of southern California. Report International Whaling Commission 40:427-431.

Hiruki, L. M., M. K. Schwartz, and P. L. Boveng, 1999. "Hunting and social behaviour of leopard seals (*Hydrurga leptonyx*) at Seal Island, South Shetland Islands, Antarctica," Journal of Zoology 249, 97-109.

Hoelzel, A. R., 2003. Marine Mammal Biology: An Evolutionary Approach (Blackwell Publishing, Malden MA).

Hohn, A. A., D. S. Rotstein, C. A. Harms, and B. L. Southall, 2006a. "Multispecies mass stranding of pilot whales (*Globicephala macrorhynchus*), minke whale (*Balaenoptera acutorostrata*), and dwarf sperm whales (Kogia sima) in North Carolina on 15-16 January 2005," (Department of Commerce), p. 222.

Hohn, A. A., D. S. Rotstein, C. A. Harms, and B. L. Southall, 2006b. "Report on marine mammal unusual mortality event UMESE0501Sp: Multispecies mass stranding of pilot whales (Glob*icephala macrorhynchus*), minke whale (*Balaenoptera acutorostrata*), and dwarf sperm whales (*Kogia sima*) in North Carolina on 15-16 January 2005," p. 222.

Houser, D. S., R. Howard, and S. Ridgway, 2001. "Can diving-induced tissue nitrogen supersaturation increase the chance of acoustically driven bubble growth in marine mammals?," J. theor. Biol. 213, 183-195.

ICES, 2005a. Report of the Ad-hoc Group on the Impacts of Sonar on Cetaceans and Fish- 2nd edition. International Council for the Exploration of the Sea. ICES AGISC CM 2005/ACE:06. 25 pp.

ICES, 2005b. Answer to DG Environment request on scientific information concerning impact of sonar activities on cetacean populations. International Council for the Exploration of the Sea. 5 pp.

Jaquet, N., D. Gendron, and A. Coakes. 2003. Sperm whales in the Gulf of California: Residency, movements, behavior, and the possible influence of variation in food supply. Marine Mammal Science 19(3):545-562.

Jasny, M., J. Reynolds, C. Horowitz, and A. Wetzler, 2005. "Sounding the Depths II: The rising toll of sonar, shipping, and industrial ocean noise on marine life. Natural Resources Defense Council. 84 pp.

Jefferson, T. A., D. Fertl, M. Michael, and T. D. Fagin, 2006. "An unusual encounter with a mixed school of melon-headed whales (*Peponocephala electra*) and rough-toothed dolphins (*Steno bredanesis*) at Rota, Northern Mariana Islands," Micronesica 38, 239-244.

Jensen, A. S. and G. K. Silber, 2004. Large whale ship strike database. NOAA Technical Memorandum NMFS-OPR-25, January 2004.

Jepson, P. D., M. Arbelo, R. Deaville, I. A. R. Patterson, P. Castro, J. R. Baker, E. Degollada, H. M. Ross, P. Herráez, A. M. Pocknell, E. Rodriguez, F. E. Howie, A. Espinosa, R. J. Reid, J. R. Jaber, V. Martin, A. A. Cunningham, and A. Fernandez, 2003. "Gas-bubble lesions in stranded cetaceans," Nature 425, 575-576.

Jepson, P. D., P. M. Bennett, C. R. Allchin, R. J. Lae, T. Kuiken, J. R. Baker, E. Rogan, and J. K. Kirkwood, 1999. "Investigating potential associations between chronic exposure to polychlorinated biphenyls and infectious disease mortality in harbour porpoises from England and Wales," The Science of the Total Environment 243/244, 339-348.

Jepson, P. D., P. M. Bennett, R. Deaville, C. R. Allchin, J. R. Baker, and R. J. Law, 2005. "Relationships between polychlorinated biphenyls and health status in harbor porpoises (Phocoena phocoena) stranded in the United kingdom," Environ. Toxicol. Chem. 24 238-248.

Johnson, J. H. and T. H. Woodley, 1998. A survey of acoustic harassment device (AHD) use in the Bay of Fundy, NB, Canada. Aquatic Mammals 24:51-61.

Kennedy, S., T. Kuiken, P. D. Jepson, R. Deaville, M. Forsyth, T. Barrett, M. W. G. v. Bildt, A. D. M. E. Osterhaus, T. Eybatov, C. Duck, A. Kydyrmanov, I. Mitrofanov, and S. Wilson, 2000. "Mass die-off of Caspian seals caused by canine distemper virus," Emerging Infectious Diseases 6, 637-639.

Ketten, D., 2005. "Beaked whale necropsy findings for strandings in the Bahamas, Puerto Rico, and Madeira, 1999-2002," (Woods Hole Oceanographic Institution, Woods Hole, MA), p. 36.

Kirschvink, J. L., A. E. Dizon, and J. A. Westphal, 1986. "Evidence from strandings for geomagnetic sensitivity in cetaceans," J. Exp. Biol. 120, 1-24.

Klinowska, M., 1985. "Cetacean live stranding sites relate to geomagnetic topography," Aquat. Mammals 11, 27-32.

Klinowska, M., 1986. "Cetacean live stranding dates relate to geomagnetic disturbances," Aquat. Mammals 11, 109-119.

Knowlton, A. R., F. T. Korsmeyer, J. E. Kerwin, H. Y. Wu, and B. Hynes, 1995. The hydrodynamic effects of large vessels on right whales. Final Report to NOAA Fisheries. NMFS Contract No. 40EANFF400534. 81 p.

Knowlton, A. R., and S. D. Kraus, 2001. Mortality and serious injury of northern right whales (Eubalaena glacialis) in the western North Atlantic Ocean. Journal of Cetacean Research and Management (Special Issue) 2:193-208.

Kompanje, E. J. O., 1995. "On the occurrence of spondylosis deformans in white-beaked dolphins *Lagenorhynchus albirostris* (Gray, 1846) stranded on the Dutch coast," Zooligische Mededekingen Leiden 69, 231-250.

Lahvis, G. P., R. S. Wells, D. W. Kuehl, J. L. Stewart, H. L. Rhinehart, and C. S. Via, 1995. "Decreased lymphocyte responses in free-ranging bottlenose dolphins (*Tursiops truncatus*) are associated with increased concentrations of PCBs and DDT in peripheral blood," Environmental Health Perspectives 103, 67-72.

Laist, D. W., A. R. Knowlton, J. G. Mead, A. S. Collet, and M. Posesta, 2001. "Collisions between ships and whales," Mar. Mammal Sci. 17, 35-75.Le Boeuf, B. J., and J. Reiter, 1991. "Biological effects associated with El Nino Southern Oscillation, 1982-83m on northern elephant seals breeding at Ano Nuevo, California," in Pinnipeds and El Nino: Responses to Environmental Stress, edited by F. Trillmich, and K. A. Ono (Springer-Verlag, Berlin), pp. 206-218.

Learmonth, J. A., C. D. Macleod, M. B. Santos, G. J. Pierce, H. Q. P. Crick, and R. A. Robinson, 2006. "Potential effects of climate change on marine mammals," Oceanography and Marine Biology: an Annual Review 44, 431-464.

Madsen, P. T., M. A. Johnson, P. J. Miller, A. N. Soto, J. Lynch, and P. L. Tyack,. 2006. Quantitative measures of air-gun pulses recorded on sperm whales (*Physeter macrocephalus*) using acoustic tags during controlled exposure experiments. Journal of the Acoustic Society of America 120(4):2366-2379.

Maldini, D., L. Mazzuca, and S. Atkinson, 2005. "Odontocete stranding patterns in the main Hawaiian islands (1937-2002): How do they compare with live animal surveys?," Pacific Science 59, 55-67.

Maybaum, H. L., 1989. Effects of a 3.3 kHz sonar system on humpback whales, *Megaptera noveangliaea*, in Hawaiian waters. Thesis, Masters of Science, University of Hawaii Manoa, August 1989. 112 p.

Maybaum, H. L., 1993. Responses of humpback whales to sonar sounds. Journal of the Acoustical Society of America 109:2455.

Mazzuca, L., S. Atkinson, B. Keating, and E. Nitta, 1999. "Cetacean mass strandings in the Hawaiian Archipelago, 1957-1998," Aquat. Mammals 25, 105-114.

McDonald, M. A., J. A. Hildebrand, and S. M. Wiggins, 2006. "Increases in deep ocean ambient noise in the northeast pacific west of San Nicolas Island, California" Journal of the Acoustical Society of America. 120(2):711-718.

Michel, J, R. Nairn, J. A. Johnson, and D. Hardin, 2001. Development and design of biological and physical monitoring protocals to evaluate the long-term impacts of offshore dredging operations on the marine environment. Final Report to the U.S. Department of Interior, Minerals Management Service, International Activities and Marine Minerals Divisions (INTERMAR), Herndon, CA. Contract No. 14-35-0001-31051. 116 p.

Mignucci-Giannoni, A. A., G. M. Toyos-Gonzalez, J. Perez-Padilla, M. A. Rodriguez-Lopez, and J. Overing, 2000. "Mass stranding of pygmy killer whales (*Feresa attenuata*) in the British Virgin Islands," J. Mar. Biol. Ass. U. K. 80, 759-760.

Marine Mammal Commission (MMC), 1999. Marine Mammals and Persistent Ocean Contaminants: Proceedings of the Marine Mammal Commission Workshop Keystone, Colorado, 12-15 October 1998.

Moeller, J., R. B., 2003. "Pathology of marine mammals with special reference to infectious diseases," in Toxicology of Marine Mammals, edited by J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea (Taylor & Francis, London), pp. 3-37.

Moore, M.J. and G.A. Early., 2004. Cumulative sperm whale bone damage and the bends. Science 306:2215.

Moore, M. J., B. Rubinstein, S. A. Norman, and T. Lipscomb, 2004. "A note on the most northerly record of Gervais' beaked whale from the western North Atlantic Ocean," J. Cetacean Res. Manage. 6, 279-281.

Moore, S. E., 2005. "Long-term Environmental Change and Marine Mammals," in Marine Mammal Research: Conservation Beyond Crisis, edited by J. E. Reynolds, W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen (John Hopkins University Press, Baltimore), pp. 137-147.

Morimitsu, T., T. Nagai, M. Ide, H. Kawano, A. Naichuu, M. Koono, and A. Ishii, 1987. "Mass stranding of odontoceti caused by parasitogenic eighth cranial neuropathy," Journal of Wildife Diseases 23, 586-590.

National Marine Fisheries Service (Office of Protected Resources), 2005. "Assessment of Acoustic Exposures on Marine Mammals in Conjunction with USS Shoup Active Sonar Transmissions in the Eastern Strait of Juan de Fuca and Haro Strait, Washington, 5 May 2003."

Nielsen, J. B., F. Nielsen, P. Jorgensen, and P. Grandjean, 2000. "Toxic metals and selenium in blood from pilot whales (*Globicephala melas*) and sperm whales (*Physeter catodon*)," Marine Pollution Bulletin 40, 348-351.

Nieri, M. E. Grau, B. Lamarch, A. Aguilar, 1999. Mass mortality of Atlantic spotted dolphin (Stenella frontalis) caused by a fishing interaction in Mauritania. (Marine Mammal Science 15(3):847-854).

National Marine Fisheries Service (NMFS), 1997. Investigation of scientific information on the impacts of California sea lions and Pacific harbor seals on salmonids and on the coastal ecosystems of Washington, Oregon, and California. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC-28. 172 pp.

———, 2004. "Interim Report on the Bottlenose Dolphin (*Tursiops truncatus*) Unusual Mortality Event Along the Panhandle of Florida, March-April 2004," (National Marine Fisheries Service), pp. 1-36.

———, 2005a. Pygmy Sperm Whale (*Kogia breviceps*): Western North Atlantic Stock. Stock Assessment Report. December, 2005.

———, 2005b. Long-Finned Pilot Whale (*Globicephala melas*): Western North Atlantic Stock. Stock Assessment Report. December, 2005.

———, 2005c. Dwarf Sperm Whale (*Kogia si*ma): Western North Atlantic Stock. Stock Assessment Report. December 2005.

———, 2005d. Harbor Porpoise (*Phocoena phocoena*): Gulf of Maine/Bay of Fundy Stock. Stock Assessment Report. December 2005.

———, 2007. "Draft Programmatic Environmental Impact Statement for the Marine Mammal Health and Stranding Response Program," (National Marine Fisheries Service, Office of Protected Resources), p. 1006.

———, 2007a. FAQs about Marine Mammal Strandings. Retrieved from http://www.nmfs.noaa.gov/pr/health/faq.htm, January 30, 2007.

———, 2007b. National Marine Fisheries Service, Office of Protected Resources. Hawaii Viewing Guidelines. Accessed 2/14/07. http://www.nmfs.noaa.gov/pr/education/hawaii/guidelines.htm

Norman, S. A., and J. G. Mead,2001. "*Mesoplodon europaeus*," Mammalian Species 688, 1-5.

Norman, S. A., S. Raverty, B. McClellan, A. Pabst, D. Ketten, M. Fleetwood, J. K. Gaydos, B. Norberg, L. Barre, T. Cox, B. Hanson, and S. Jeffries, S., 2004. "Multidisciplinary investigation of stranded harbor porpoises (*Phocoena phocoena*) in Washington State with an assessment of acoustic trauma as a contributory factor (2 May – 2 June 2003)," (United States Department of Commerce), p. 120.

Nowacek, D., M.P. Johnson, and P.L. Tyack, 2004. North Atlantic right whales (*Eubalaena glacialis*) ignore ships by respond to alerting stimuli. Proceedings of the Royal Society of London, Series B. Biological Sciences 271:227-231.

Nowacek, D.P., L.H. Thorne, D.W. Johnston, and P.L. Tyack, (2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37(2):81-115.

National Research Council (NRC), 1994. "Low-frequency Sound and Marine Mammals: Current Knowldege and Research Needs". (National Research Council of the National Academes, National Academes Press, Washington, DC).

———, 1996. "Natural Climate Variability on Decade-to-Century Time Scales". (National Research Council of the National Academes, National Academes Press, Washington, DC).

———, 2000. "Marine Mammals and Low-Frequency Sound-Progress Since 1994". (National Research Council of the National Academes, National Academes Press, Washington, DC).

NRC, 2003. "Ocean Noise And Marine Mammals". (National Research Council of the National Academes, National Academes Press, Washington, DC).

NRC, 2005. "Marine Mammal Populations and Ocean Noise". (National Research Council of the National Academes, National Academes Press, Washington, DC).

NRC, 2006. "Dynamic Changes in Marine Ecosystems: Fishing, Food Webs, and Future Options, Committee on Ecosystem Effects of Fishing: Phase II - Assessments of the Extent of Change and the Implications for Policy," (National Research Council, of the National Academes, National Academes Press, Washington, DC).

Odell, D.K., 1987. The mystery of marine mammal strandings. Cetus 7:2.

O'Hara, T. M. and C. Rice, 1996. Polychlorinated biphenyls. In: A. Fairbrother, L. Locke, and G Hoff (eds). Noninfectious diseases of wildlife, 2nd edition. Iowa State University Press, Ames, Iowa.

O'Hara, T. M., M. M. Krahn, D. Boyd, P. R. Becker, and L. M. Philo,1999. Organochlorine contaminant levels in eskimo harvested bowhead whales of arctic Alaska. Journal of Wildlife Diseases 35(4):741-752.

O'Shea, T. J., and R. L. Brownell, Jr., 1994. Organochlorine and metal contaminants in baleen whales: a review and evaluation of conservation implications. Science of the Total Environment 154:179-200.

Osborne, R., 2003. "Historical Information on Porpoise Strandings in San Juan County Relative to the May 5th Navy Sonar Incident," (The Whale Museum News and Events).

Pace, R. M, and G. K. Silber, 2005 Abstract- Simple analyses of ship and large whale collisions: Does speed kill? Sixteenth Biennial Conference on the Biology of Marine Mammals, San Diego, December 2005.

Palka, D. and M. Johnson (eds), 2007. Cooperative Research to Study Dive Patterns of Sperm Whales in the Atlantic Ocean. Minerals Management Service, New Orleans, LA. OCS Study MMS2007-033. 49 pp.

Parente, C. L., J. P. Araujo, and M. E. Araujo,. 2007. Diversity of cetaceans as tool in monitoring environmental impacts of seismic surveys. Biota Neotrop 7(1):1-7.

Paterson, R. A., 1984. "*Spondylitis deformans* in a Bryde's whale (Balaenoptera edeni Anderson) stranded on the southern coast of Queensland," Journal of Wildife Diseases 20, 250-252.

Perrin, W. F., and J. R. Geraci, 2002. "Stranding," in Encyclopedia of Marine Mammals, edited by W. F. Perrin, B. Wursig, and J. G. M. Thewissen (Academic Press, San Diego), pp. 1192-1197.

Piantadosi, C. A., and E. D. Thalmann, 2004. "Whales, sonar and decompression sickness," Nature 15 April 1-2.

Pitman, R. L., L. T. Ballance, S. L. Mesnick, and S. J. Chivers, 2001. "Killer whale predation on sperm whales: Observations and implications," Mar. Mammal Sci. 17, 494-507.

Podesta, M., A. D'Amico, G. Pavan, A. Drouga, A. Komnenou, and N. Portunato, 2006). A review of *Ziphius cavirostris* strandings in the Mediterranean Sea. Journal of Cetacean Research and Mangagement 7(3):251-261.

Polefka, S., 2004. Anthropogenic Noise and the Channel Islands National Marine Sanctuary. Report by Environmental Defense Center, Santa Barbara, CA. 51 pp.

Rankin, J. J., 1953. "First record of the rare beaked whale, Mesoplodon europaeus, Gervais, from the West Indies," Nature 172, 873-874.

Read, A. J., P. Drinker, and S. Northridge, 2006. "Bycatch of marine mammals in U.S. and global fisheries," Conservation Biology 20, 163-169.

Resnick, D., and G. Niwayama, 2002. "Ankylosing spondylitis," in Diagnosis of bone and joint disorders, edited by D. Resnick (W.B. Saunders Co., Philadelphia), pp. 1023-1081.

Ross, D., 1976. Mechanics of underwater noise. Pergamon, New York. 375 pp.

Richardson, W. J., C. R. Greene, Jr., C. I. Malme, and D. H. Thomson, 1995). Marine Mammals and Noise (Academic Press, New York).

Ridgway, S. H., and Dailey, M. D., 1972). "Cerebral and cerebellar involvement of trematode parasites in dolphins and their possible role in stranding," J. Wildlife Dis. 8, 33-43.

Ridgway, S. H., and R. Howard, 1979. "Dolphin lung collapse and intramuscular circulation during free diving: evidence from nitrogen washout," Science 206, 1182-1183.

Robinson, S., L. Wynen, and S. Goldsworthy, 1999. "Predation by a Hooker's sea lion (*Phocarctos hookeri*) on a small population of fur seals (*Arctocephalus* spp.) at Macquarie Island," Mar. Mammal Sci. 15, 888-893.

Ross, P. E., R. L. DeSwart, R. F. Addison, H. VanLoveren, J. G. Vos, and A. Osterhaus, 1996. "Contaminant-induced immunotoxicity in harbour seals: wildlife at risk?," Toxicology 112, 157-169.

Simmonds, M.P. and L.F. Lpez-Jurado, (1991. Whales and the military. Nature 351:448.

Secchi, E. R., and S. Zarzur, 1999. "Plastic debris ingested by a Blainville's beaked whale, *Mesoplodon densirostris*, washed ashore in Brazil," Aquat. Mammals 25, 21-24.

Selzer, L. A., and P. M. Payne, 1988). "The distribution of white-sided dolphins (*Lagenorhynchus acutus*) and common dolphins (*Delphinus delphis*) vs. environmental features of the continental shelf of the northeastern United States," Mar. Mammal Sci. 4, 141-153.

Sergeant, D. E., 1982. "Some biological correlates of environmental conditions around Newfoundland during 1970-1979: harp seals, blue whales and fulmar petrels," (North Atlantic Fisheries Organization. NAFO. Scientific Council Studies), pp. 107-110.

Simmonds, M. P, and J. D. Hutchinson, 1996. "The Conservation of Whales and Dolphins: Science and Practice". John Wiley & Sons, Chichester, UK.

Simmonds, M. P., and L. F. Lopez-Jurado, 1991. "Whales and the military," Nature 351, 448.

Simmonds, M. P., and S. J. Mayer, 1997. "An evaluation of environmental and other factors in some recent marine mammal mortalities in Europe: implications for conservation and management," Environmental Review 5, 89-98.

Smithsonian Institution, 2000. Cetacean Distributional Database. Marine Mammal Program, Smithsonian Institution, Washington, DC.

Soto, N.A., M. Johnson, P.T. Madsen, P.L. Tyack, A. Bocconcelli, J.F. Borsani, 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*). Marine Mammal Science 22(3): 690-699.

Southall, B. L., R. Braun, F. M. D. Gulland, A. D. Heard, R. W. Baird, S. M. Wilkin, and T. K. Rowles, 2006. "Hawaiian melon-headed whale (Peponocephala electra) mass stranding event of July 3-4, 2004," 73 pp.

Southall, B. L., 2008. Declaration of Brandon Southall, PhD for OCEAN MAMMAL INSTITUTE, et al., Plaintiffs, v. ROBERT M. GATES, Secretary of the Department of Defense, et al., Defendants. United States Court for the District of Hawaii. No. CV07-00254 DAE LEK

Stone, C. J. and M. J. Tasker, 2006. The effects of seismic airguns on cetaceans in U.K. waters. Journal of Cetacean Research and Management 8(3):255-263.

Struntz, W. D. J., J. R. Kucklick, M. M. Schantz, P. R. Becker, W. E. McFee, and M. K. Stolen, 2004. "Persistent organic pollutants in rough-toothed dolphins (*Steno bredanensis*) sampled during an unusual mass stranding event," Marine Pollution Bulletin 48, 164-192.

Sweeny, M. M., J. M. Price, G. S. Jones, T. W. French, G. A. Early,, and M. J. Moore, 2005. "Spondylitic changes in long-finned pilot whales (*Globicephala melas*) stranded on Cape Cod, Massachusetts, USA, between 1982 and 2000," J. Wildlife Dis. 41, 717-727.

Tarpley, R. J., and S. Marwitz, 1993. "Plastic debris ingestion by cetaceans along the Texas coast: two case reports," Aquat. Mammals 19, 93-98.

Trites, A. W., V. Christensen, and D. Pauly, 1997. "Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean," Journal of Northwest Atlantic Fishery Science 22, 173-187.

Urick, R.J., (1983). Principles of Underwater Sound for Engineers, McGraw-Hill, NY.

U.S. Department of Navy, 2001. Final Overseas Environmental Impact Statement and Environmental Impact Statement for Surveillance Towed Array Sensor System Low Frequency Active (SURTASS LFA) Sonar-Volume 1.

U.S. Department of Navy, 2004. Report on the Results of the Inquiry into Allegations of Marine Mammal Impacts Surrounding the Use of Active Sonar by USS SHOUP (DDG 86) in the Haro Strait on or about 5 May 2003.

Van Dolah, F. M., 2005. "Effects of Harmful Algal Blooms," in Marine Mammal Research, edited by J. E. Reynolds, W. F. Perrin, R. R. Reeves, S. Montgomery, and T. J. Ragen (John Hopkins University Press, Baltimore), pp. 85-99.

Van Dolah, F. M., G. J. Doucette, F. M. D. Gulland, T. L. Rowles, and G. D. Bossart, 2003. "Impacts of algal toxins on marine mammals," in Toxicology of Marine Mammals, edited by J. G. Vos, G. D. Bossart, M. Fournier, and T. J. O'Shea (Taylor & Francis, London), pp. 247-269.

Vanderlaan, A. S. M., and C. T. Taggart, 2007. Vessel collisions with whales: the probability of lethal injury based on vessel speed. Marine Mammal Science 23(1):144-156.

Vidal, O., and J. P. Gallo-Reynoso, 1996. "Die-offs of marine mammals and sea birds in the Gulf of California, Mexico," Mar. Mammal Sci. 12, 627-635.

Visser, I. K. G., J. S. Teppema, and A. D. M. E. Ostrhaus, 991. "Virus infections of seals and other pinnipeds," Reviews in Medical Microbiology 2, 105-114.

Walker, M. M., J. L. Kirschvink, G. Ahmed, and A. E. Dizon, 1992. "Evidence that fin whales respond to the geomagnetic field during migration," J. Exp. Biol. 171, 67-78.

Walker, R. J., E. O. Keith,A. E. Yankovsky, and D. K. Odell, 2005. "Environmental correlates of cetacean mass stranding sites in Florida," Mar. Mammal Sci. 21, 327-335.

Walsh, M. T., R. Y. Ewing, D. K. Odell, and G. D. Bossart2001. "Mass Strandings of Cetaceans," in Marine Mammal Medicine, edited by L. A. Dierauf, and F. M. D. Gulland (CRC Press, Boca Raton), pp. 83-96.

Wartzok, D., and D. Ketten, 1999. “Marine mammal sensory systems,” in The Biology of Marine Mammals, edited by J. E. Reynolds, and S. A. Rommel (Smithsonian Institution Press, Washington, DC).

Weise, M. J., D. P. Costa, and R. M. Kudela, 2006. “Movement and diving behavior of male California sea lion (*Zalophus californianus)* during anomalous oceanographic conditions of 2005,” Geophysical Research Letters 33, L22S10.

Whitaker, B. R., J. R. Geraci, and A. Stamper1994. “The near-fatal ingestion of plastic by a pygmy sperm whale, *Kogia breviceps*,” in IAAAM Proceedings, edited by B. Fenwick (Vallejo, CA), p. 108.

Whitehead, H., 2003. Sperm whales. University of Chicago Press, Chicago, Illinois.

Wilkinson, D. M., 1991. “Report to the Assistant Administrator for Fisheries, in Program Review of the Marine Mammal Stranding Networks,” (U.S. Department of Commerce, NOAA, National Marine Fisheries Service, Silver Springs, MD), pp. 1-171.

Wilson, J., L. Rotterman, and D. Epperson., 2006. Minerals Management Service Overview of Seismic Survey Mitigation and Monitoring on the U.S. Outer Continental Shelf. Presented to the Scientific Committee of the International Whaling Commission, SC/58/E8. 13 pp.

Wittnich, C., M. Belanger, N. Askin, K. Bandali, and W. J. Wallen2004. “Awash in a sea of heavy metals: mercury pollution and marine animals,” (Oceanographic Environmental Research Society and Canadian Marine Animal Rescue Network), pp. 1-70.

Ylitalo, G. M., J. E. Stein, T. Hom, L. L. Johnson, K. L. Tilbury, A. J. Hall, T. Rowles, D. Greig, L. J. Lowenstine, and F. M. D. Gulland, 2005. “The role of organochlorines in cancer-associated mortality in California sea lions (*Zalophus californianus*),” Marine Pollution Bulletin 50, 30-39.

Zeeber, J. A. Corten, and E. de Graaf., 2006. Bycatch and release of pelagic megafauna in industrial trawler fisheries off Northwest Africa. Fisheries Research 78:186-195.

Zimmerman, S. T., 1991. A history of marine mammal stranding networks in Alaska, with notes on the distribution of the most commonly stranded cetacean species, 1975-1987 In: J.E. Reynolds, and D.K. Odell 9ed). Marine Mammal Strandings in the United States: Proceedings of the Second Marine Mammal Stranding Workshop. NOAA Technical Report NMFS 98.